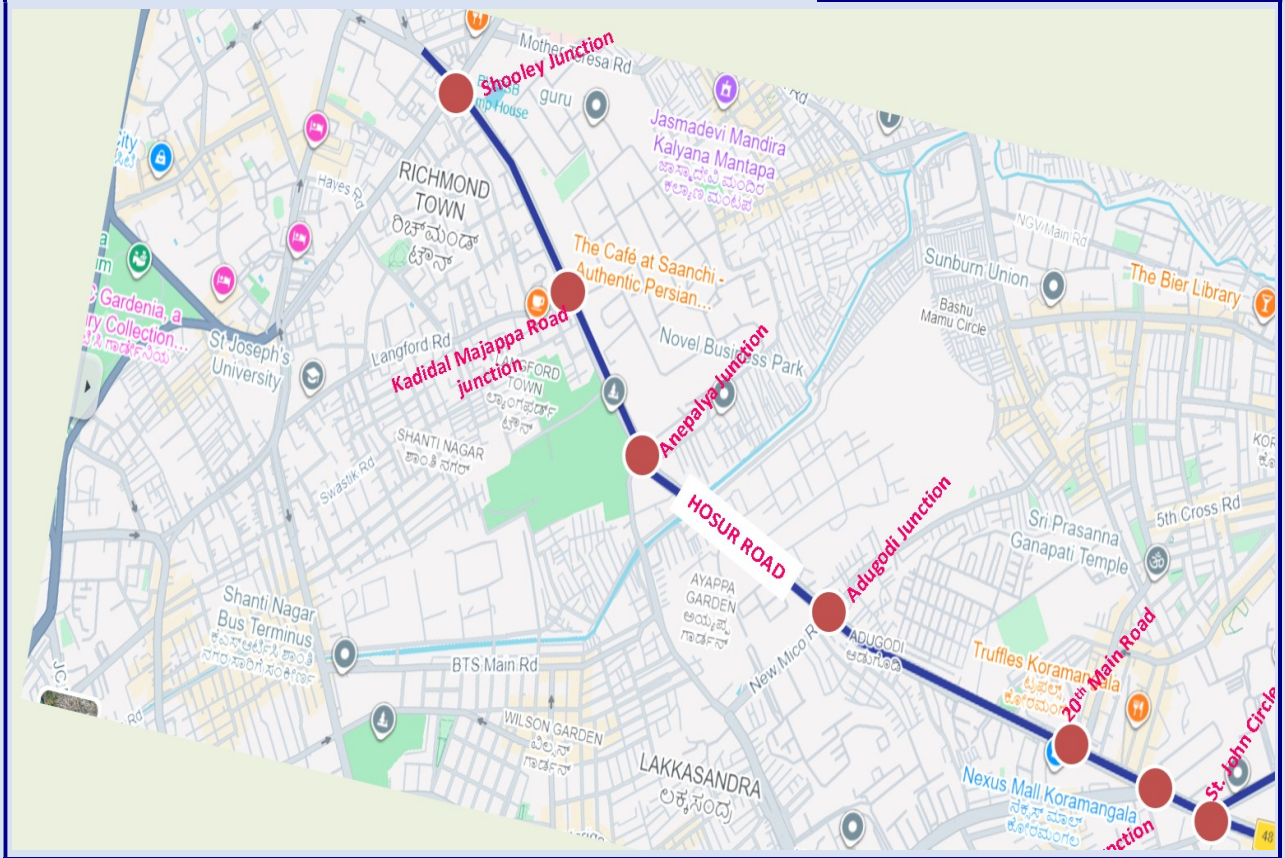
CLIENT	**BENGALURU SMART INFRASTRUCTURE LIMITED (B-SMILE)** **#108,1st Floor, Annexe-2 Building** **N.R. Square, Bangalore**
PROJECT	Consultancy Services for Preparation of Detailed Project Report for Proposed Construction of **Elevated Corridors from Shooley Circle to St. John Hospital Road along Hosur Road via Anepalya Junction and Adugodi Junction in Bengaluru Central and South City Corporation limits.**
Title:	**DETAILED PROJECT REPORT (VOLUME-1)**
Doc No.	Report No. NC/B-SMILE/HOSUR/DPR/01



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Chapter – 1 –INTRODUCTION

1.1 Background

1.1.1 Bangalore, the Capital of Karnataka is the Fifth Largest City in the Country and is growing at a rate, which is significantly higher than that of others. Due to the Growth in Economic Activities, the city is attracting migrants. To serve this Influx of Population, Residential Layouts are being developed. But adequate Transport Infrastructure Facilities such as Roads, Grade Separators, Subways, Mass Transit System, etc. to match this demand are conspicuously absent. The additional demand is to be catered by the already Saturated Road Network. Due to the Inherent Road Network in Bangalore, there are on the average 2 Major and 2 Minor Junctions per kilometre of Road Length. This has resulted in increase in Travel Time due to frequent Bottlenecks and Breakdowns.

1.1.2 The Urban Form of Bangalore is characterized by a Radio – Concentric System structured by Ring Roads, Five Major Radial Roads and Five Secondary Radial Roads. The Five Major Radial Roads are Mysore Road (SH – 17) in the South / Southwest, Old Madras Road (NH – 4) in the North / Northeast, Bellary Road in the North, Hosur Road (NH – 7) in the South – East and Tumkur Road in the North – West. Similarly, the Five Secondary Radial Roads include Magadi Road (SH – 17E) in the West, Kanakapura Road (NH – 209) in the South, Bannerghatta Road (SH – 48) in the South, Varthur Road and Whitefield Road (SH – 37) in the East. The differentiated development of the city based on Geographical Sectors and the Star like Growth Array along the Major Roads, mark the change from a Concentric Spatial Growth to a Sectorial and Linear Radial Development.

1.1.3 The city had a population of 140.0 Lakhs. The extent of Developed Area has also increased considerably; in 1971 the Area was 174.7 Sq. km. and today it is about 805 Sq. km. In absence of Adequate Mass Transportation System, the use of personal motor vehicles for intra – city travel has increased substantially. This has resulted in growth of motor vehicles, which is four times the rate of population growth in the last two decades (1.91 Lakh vehicles in 1981 and 23 Lakh vehicles in 2005). The Public Transport System (Bus) is overstressed carrying about 50 Lakh Commuters in a daily basis. Congested Streets and Longer Route Length due to Urban Sprawl have only served to reduce Bus Frequencies further. In a recent study done by CRRI, it has been reported that annual traffic growth rates vary in the range of 2–4% in the central zone, 5 -7% in the intermediate zone and 8 – 9% on the regional roads in Bangalore City. CRRI study also reported delays of 26.8 sec per km of travel and 9.9 seconds per minute of travel.

1.1.4 The combined effect of all these on the Road Network of Bangalore is Delay and Congestion beyond Tolerable Limits. Vehicular Conflicts at the Intersections are being eliminated by Traffic Signals but at the Expense of Delays and Long Queues. The Peak Hour has spread over a longer period, since there are no Perceptible Capacity Augmentation / Conflict Reduction Measures. Traffic related Problems have become Regular Phenomena on Bangalore Roads, due to the Vast Developments. This fact is substantiated by the Traffic Study Results at various Road Networks and Intersections of the City. Most of the Major Junctions of the Core City have crossed the mark of 10000 PCUs in the Peak Hour. Though number of Grade Separators have been constructed and are being constructed, most of them are in the Developed Part of the City and causing a Trigger of Congestion at adjacent Junctions. Traffic Management Measures such as One Way Systems, Parking Restrictions, Junctions Improvements, etc. are being implemented to ease the Congested Street Network. But the ever-increasing Traffic is fast deteriorating the Limited Improvement in Level of Service these Traffic Management Measures can offer.

1.1.1 **B- SMILE**, Bengaluru Smart Infrastructure Limited, a Special Purpose Vehicle (SPV) created by Karnataka government, B- SMILE responsible to oversee and implement major projects in Bengaluru. As a comprehensive solution for End to End traffic solution to the city of Bangalore the B- SMILE is planning for 120 km of elevated roads in the various part of the city to provide End to end solutions.

This Response is the Answer to the severe strain on the Urban Infrastructure, which is inevitable due to the very rapid rate of growth in traffic. Travel Demands of Passengers have increased many folds in the last two decades. Unfortunately, Growth in the Infrastructure is not commensurate with the growing demands of traffic. There is an exigent need to effectively manage the Traffic and Transportation Systems to optimize the Solutions with Short Term and Long-Term Measures.

1.1.2 One of the Practical Steps towards Optimal Solutions that will also give an Immediate Relief to Traffic Scenario is Capacity Augmentation. Capacity Augmentation is not possible without widening the high – density corridors. Increasing the capacity of important corridors is inescapable in the long run even if it entails Land Acquisition at high cost.

1.2 Sustainable Operation of the Road Network

Road transport has a significant role to play in achieving a balance between Meeting Economic and Social Needs and Preserving the Environment. Both lack of or inadequacies in the Capacity of Roads have affected the Economic Growth and Bad Roads have been recognized as Bottlenecks for all Economic Activities.

Improving the Efficiency of the way the Road Network is operated and used is a Key Aspect of Sustainable Transport.

There are several tools which can be used to deliver Sustainable Operation of the Road Networks and to assess Targets and Effectiveness, including

1. Integrated Transport Planning.
2. Improved Design.
3. Roadside Management.
4. Traffic Management.
5. Incidents / Congestion Management.
6. Road Safety Management
7. Traffic Law Enforcement.
8. Travel Demand Management
9. Integrated Transept Modes.
10. Road User Information
11. Management of Road User and Travel Behaviour.
12. Technology Use
13. Intelligent Transport System.
14. Asset Management and Road Maintenance.
15. Heavy Vehicle / Long – Distance Buses Management.
16. Data Collection and Analysis System
17. Vehicle Emissions Control.

B- SMILE, Bengaluru Smart Infrastructure Limited, a Special Purpose Vehicle (SPV) created by Karnataka government, B- SMILE responsible to oversee and implement major projects in Bengaluru. As a comprehensive solution for End-to-End traffic solution to the city of Bangalore the B- SMILE is planning for 120 km of elevated roads in the various part of the city to provide End to end solutions.

In Bangalore, Roads are approaching full capacity utilization thereby hindering Economic Growth; conversely, lack of basic Road Access is hindering growth of the Economic Activities in the City particularly for the Business Establishments and for the poor. It is estimated that about 80% of the Arterial Road Network in Bangalore is already heavily congested. The Coverage and Quality of local roads remain inadequate to serve the needs of the Industry, Government, Businesses and Citizens.

1.3 Need for the Project

The Project Junction is a part of **Hosur Road** and is one of the busiest stretches in the city. The Project Stretch is in Northeast Quadrant of Bangalore and connects NH – 44 at Hosur Road on Southern side and Bannerghatta Road on Western side and it starts from **Shooley Junction** (Towards Brigade Road) and ends at in front of **St. John Hospital** and well **before existing Madiwala Underpass**. Stretch is around 5.43 km, the peak hour traffic at various junctions along corridor are varying with morethan 10000 PCU or approaching 10000 PCU in near future. This Road is not spared even on Holidays as it is the Gateway to MG Road, Brigade Road, Richmond Road, Koramangala, Hosur etc. On western side Bannerghatta Road, Hosur Road on southern side etc., The movement of vehicles has increased on Hosur Road as it connects NH – 44, Bannerghatta Road. The Study corridor is in thickly Developed Residential and Commercial Area and is surrounded by some of the well know establishments like Forum Mall, St. John Hospital, Christ University, Bosch Company. National Military school, National dairy institute and Cristian cemetery are situated adjacent to the corridor under consideration.

B-Smile is developing Tunnel in Greater Bangalore Authority region - North-South Corridor, this Development will definitely increase the Traffic of Hosur Road at the Junction. Further, with the spurt in the economy, the Land Use Patterns of this Part of the City Area have been changing at a very fast pace since 10 years. Many of the Self Containing Residential Areas in and around this Junction, such as Koramangala, Madiwala, BTM Layout, are being converted into Partial Commercial Establishments. With this change in the Land Use Pattern, Traffic at this junction has been increased considerably in last 10 years time. Many large Residential Site are being converted into Apartments / Flats, in and around this Junction and a site that would house either a family or two now will be able to house multiple number of families and with this the number of Vehicle / Traffic also will increase manifold in a couple of years.

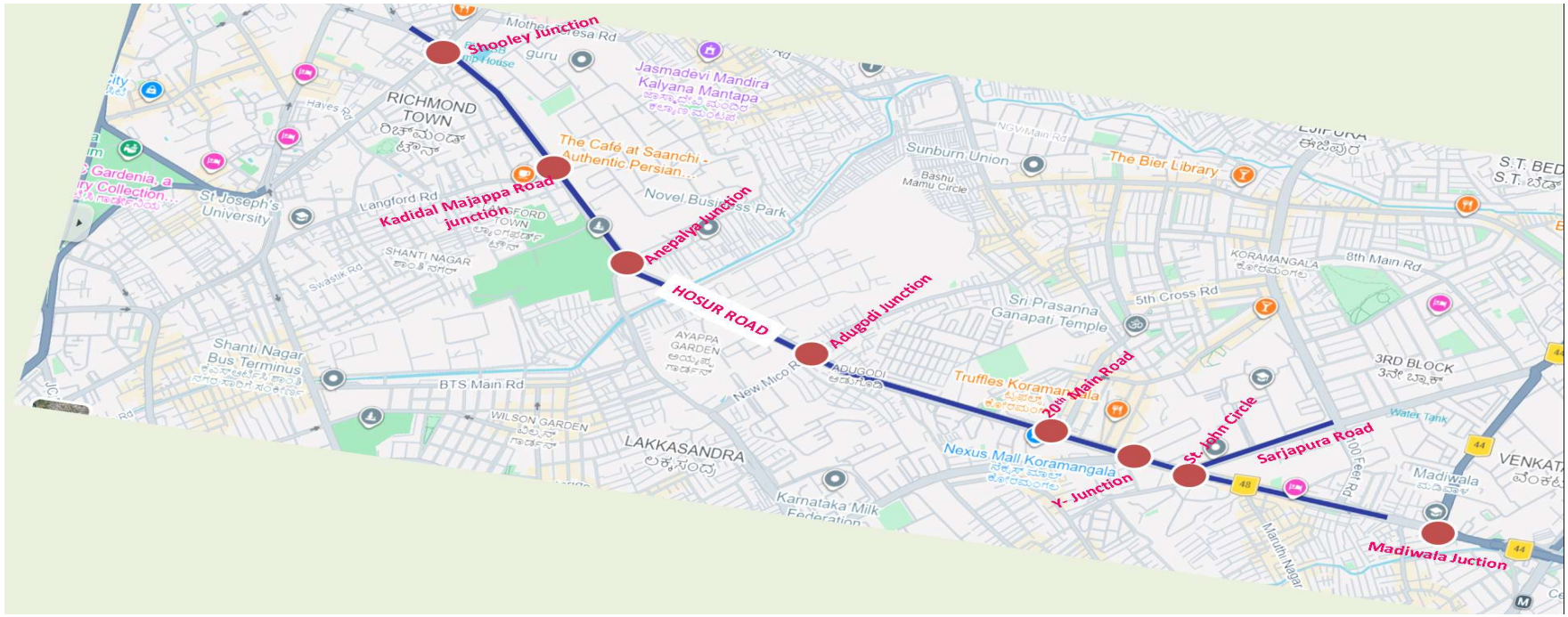
This being the Background, the B-SMILE has proposed to Construct Elevated Corridor along Hosur Road from Sholey (Towards Bridge Road) Junction to St. John Hospital -Sarjapura Road to provide Uninterrupted, Seamless Traffic Flow and to Increase Level of Service along the Junctions.

1.5 Junction proposed for Improvements

The following Junction have been taken for the proposed Improvements

- Sholey Junction (Brigade Road & Richmond Road Junction)
- Anepalya Junction (Bannerghatta Road-Hosur Road Junction)
- Adugodi Junction (New Mico Road Junction)
- 20th Main Road junction (Ganapathi temple road)
- Hosur Road Y Junction.
- St. John Hospital Junction.

Key Map of the proposed Junction Improvements is enclosed in **Annexure A.1.1**.



1.6 Contents of the Report the Methodology, as detailed in the Project Proposal, has been followed for carrying out the necessary Investigations and Preparation of this Feasibility Report.

This Report includes the following.

- Chapter 2: Objectives and Scope of Study
- Chapter 3: Project Cost
- Chapter 4: Field Studies and Investigations.
- Chapter 5: Planning and Design Criteria
- Chapter 6: Concept Proposal.
- Chapter 7: Structural System of Flyover
- Chapter 8: Traffic Diversion and Management Plan
- Chapter 9: Conclusion.

Chapter – 2 – OBJECTIVE AND SCOPE OF STUDY

2.1 Objective

Detailed Project Report for Construction of Elevated Corridor along Hosur Road from Sholey (Brigade Road) Junction to St. John Hospital -Sarjapura Road, Bangalore.

The Primary Objectives of the Study are

- To collect the data along corridor for effectively and optimally manage Traffic at Junctions and along corridor.
- To conduct necessary Surveys and Investigations to arrive at Alignment Alternatives For Traffic Improvement at Junction.
- To suggest Optimal and Feasible Grade Separation Schemes and Appurtenant Link Improvement Measures to reduce travel time.
- To improve the existing Junctions to streamline Traffic Flow at Grade Level.
- To improve the Environmental Conditions of the Junction by reducing Idle Time.
- To reduce the Vehicle Operation Cost of the Road Users.
- To reduce Accidents due to Traffic.
- To summarize, the Main Objective of the Study of this Junction is to offer to the Road
- Users commuting through this Junction to Comprehensive Connectivity, Convenience, Comfort, Affordability, Safety and Aesthetics.

2.2 Project Scope

The scope of the consultancy study involves the following -

- Review of available data and reports
- Conduct additional Geo-technical Investigations if required.
- Conduct traffic study for intended elevated road.
- Finalisation of General alignment drawing for the proposed elevated road.
- Study of “Structural System” and Evaluation.
- Preparation of Traffic Management Data.
- Preparation of preliminary designs and estimates.

- Preparation of Tender documents.

2.3 Approach Methodology:

Stage - I Field Investigation:

i. Conducting Topo Survey.
ii. Soil Investigation.
iii. Conducting Traffic Survey.

Stage - II Analysis and Designs

i. Detailed Soil investigation report as per field and lab tests at delected locations along the corridor.
ii. Preparation of GAD and discussing with the authorities for approval of the same.
iii. Preliminary Analysis of Super Structure and sub structures.
iv. Preliminary Design of Super Structure, Substructure and Foundation as per IRC Codes and specifications.
v. Preparation of schematic drawings.
vi. Preparation of detailed BOQ and cost estimates.
vii. Preparation of Tender documents.

2.4 Design Philosophy.

The Technical proposal given in this Detailed Project Report consists of Designs, Drawings and all Technical Details based on Surveys and Investigations stated in Section 2.2 above.

The Design standards adopted in the present Design are in accordance with the codal provisions of India as stipulated by the Indian Roads Congress (IRC), Indian Standards Specification (IS) and the Ministry of Road Transport & Highways. Deviations may be considered in planning parameters if extremely necessary considering the dense urban conditions, like the present one, from the present codal provisions. These modifications in

the design will be adopted based on similar projects at urban locations as "Good Engineering Practice".

The Designs and Drawings presented as a part of this report are based on the Studies, Investigations and Designs which provide a fair basis for making Detailed Designs and Drawings subsequently. The consultants opine that the detailed engineering designs and drawings will be prepared on approval of this report before construction, based on actual details at site viz., utilities, Geo Technical data and Soil profile etc.

CHAPTER – 3 – PROJECT COST

3.1 General

The project cost has been estimated mainly based on the rates derived after rate analysis using Uni SR 2024-25 Karnataka Public Works Department, supplemented by issue price list issued by the Superintending Engineer PWD (Bangalore Circle) dated: 06.01.2026, 12.01.2026. For the few items not covered in the above SR, rates from NH SR / market rates have been adopted. The Data rate for UHPFRC, which is not in SR has been workout and presented in Annexure.

The detailed estimate is enclosed as Appendix -1. At the end of the report. The bill wise cost abstract for the project ELEVATED CORRIDOR ALONG HOSUR ROAD FROM SHOLEY (BRIGADE ROAD) JUNCTION TO ST. JOHN HOSPITAL -SARJAPURA ROAD, BANGALORE

3.2 Cost Summary

CONSTRUCTION OF ELEVATED CORRIDOR ALONG HOSUR ROAD FROM SHOLEY (BRIGADE ROAD) JUNCTION TO ST. JOHN HOSPITAL -SARJAPURA ROAD, BANGALORE

Sl. No.	Items	Amount (In Rs)
1	Site clearance and dismantling	2,314,098.00
2	Compound wall construction	30,030,659.00
3	Flyover works (via duct portion)	4,487,842,323.00
4	Flyover approach works	115,033,057.00
5	Road Diversion (maintenance work during construction)	46,901,690.00
6	Drain/footpath	95,210,609.00
7	Surface level road /slip roads (post construction)	71,100,659.00
8	Road furniture & other work	12,123,141.00
9	Overhead gantry	7,205,988.00
10	Pier protection below flyover	48,832,063.00
11	Electrical works	40,000,000.00
12	Preliminary works and Design Charges	36,372,372.00
		4,992,966,660.00
	GST @ 18%	898,733,998.00
	Total Civil Cost, Rs.	**5,891,700,658.00**
i	Provision for Contingencies and Provision for Departmental Establishment Charges 2% on APT	99,859,333.20
ii	Provision for Independent Engineer / PMC @ 1.50% on APT (Including GST)	74,894,499.90
iii	Provision for Price escalation @2.5% for the 2nd year i.e., 0.5% of APT (Including GST)	124,824,166.50
iv	Provision or utility shifting @ 7% of Project cost (APT) (Including GST)	349,507,666.21
v	Provision for Arboriculture/ Afforestation @ 0.50% on APT (Including GST)	24,964,833.30
vi	Land Acquisition Cost including Structures	593,613,200.00
viii	Miscellaneous and other Department Deposits	635,641.93
	Total Project Cost	**7,160,000,000.00**

(Rupees Seven Hundred and Sixteen Crores only)

3.3 Land Acquisition:

To execute the work, it is required land and structure acquisition and cost of Rs. 59.36 Crores.

3.4 Material rates.

The Original basic price (Ex-Factory) of cement, steel and bulk bitumen exclusive of all taxes and duties considered are as per Uni SR 2024-25. The difference in rates will be added to/subtracted from the basic rates in the SR.

Chapter – 4 – FIELD SURVEYS AND INVESTIGATION

4.1 General

The Study and Investigations were in accordance with the Scope of Work entrusted to the Consultants. They include:

- Study of available data.
- Field Reconnaissance
- Additional Topography Surveys
- Additional Soil Investigations / Borehole Investigations.
- Traffic Survey and report.

4.2 Site Appreciation

The proposed project extent is from Sholey Junction to St. John Hospital junction. This corridor plays a crucial role in channelizing traffic movement from Hosur towards and from the Northern and eastern part of Bengaluru, covering major areas such as Koramangala, Madiwala, Adugodi, Shanti Nagar, Brigade Road, MG Road, BTM lay out etc.,.

At present Hosur road along the stretch is white topped and work is completed till Anepalya Storm Water Drain. Further Underground Metro works under progress beyond Anepalya, the existing traffic flow along this stretch is heavily congested and no option of diversion of traffic. This leads to frequent bottlenecks, reduced travel speed, and increased travel time, particularly during peak hours. The traffic is almost uniform for major part of the day. The project site thus lies in a high-demand traffic corridor with continuous vehicular movement, indicating the necessity of capacity augmentation and improved connectivity.

The proposed Elevated Corridor has a total length of approximately 5.43 km including entry and exit ramps at varies locations, traverses across 6 major junctions, namely:

a) Sholey Junction

b) Kadidal Manjappa Road Junction.

c) Anepalya Junction.

d) Adugodi Junction - Four-Legged Junction.

e) 20th Main Road Junction - 3-Legged Junction.

f) Y Junction - 3 legged junction.

g) St. John Hospital junction - 4-legged junction.

4.3 Type of Junctions

Name of Junction	Type of Junction
Sholey Junction	3-Legged junction
Kadidal Manjappa Road junction	3-Legged junction
Anepalya Junction	4-Legged Junction
Adugodi Junction	4-Legged Junction
Koramangala 20th Main Road Junction	3-Legged junction
Y- Junction	3-Legged Junction
St. John Hospital junction	4-Legged Junction

4.4 ROW and Gradient of Existing Roads along the Stretch

Name of Road	Gradient	ROW
Shooley Junction	flat in nature	19.5m to 30.2m
Kadidal Manjappa Road Junction	Falling towards Adugodi	19.5m to 20.0m
Anepalya Junction	Falling towards Adugodi and Bannerghatta Road.	In between Kadidal Manjappa road to Anepalya 26.75m to 34.8m Further it reduces to 20.1m towards Adugodi.
Adugodi Junction	Falling towards Anepalya Junction	31.7 to 30m.
Koramangala 20th	Falling gradient towards	30.3m to 34m.

Main Road Junction	Koaramangala & flat gradient along hosur road.	From 20th main road to Y junction having slip road with -3.7m level variation from main road.
Y- Junction	Falling gradient towards Madiwala	Along hosur road 28.9m to 39.4m Toward Dairy junction 20.5 to 21.5m
St. John Hospital junction	Hosur Road Falling gradient towards Madiwala	34.6m to 38m

The traffic at the junction mainly due to cars, two wheelers, Buses and Auto rikshaws with considerable amount of goods and commercial vehicles. The traffic at the junction leads to residential areas of surrounding places, Commercial Establishment, Hospitals (St. John) tourist attraction MG Road, Bridge Road, Military school, National dairy institute etc., At present, traffic at the junctions is managed by means of automatic signal system with considerable delay during peak hours. Side drain exists on both side of carriage way. The land use within the project area is mostly commercial establishments and public buildings.

4.5 Major existing structure across the alignment

- There are 4 Pedestrian Skywalks are existed along the stretch which are to relocated / remodel the skywalk structure.
- Under Ground BMRCL metro line Crossing near Anepalya Junction.

4.6 Reconnaissance Survey

The consultants visited the site to acquaint themselves with the site and to study the various site related constraints which should be kept in mind while preparing the various alternatives solutions for reducing the delay at the junction.

- The Traffic at Shooley junction, Kadidal Majappa Road Junction, Anepalya Junction, Adugodi Junction, 20th Main Road Junction, Y Junction and St. John Hospital junction are controlled by automatic Signals.
- In this existing stretch the road width is varying from 19.5m to 38.0m from Shooley junction to Sarjapura road junction. the general topography in the stretch is having curves with varying horizontal alignment. There are developments in terms commercial establishments along this Stretch on both sides. Generally, Utilities are in footpath portion. Bus stops are found at both side of stretch.
- White topping work is completed till Anepalya Junction from Sarjapura Road.

4.7 Topographic Survey

Topographical surveys were conducted to capture the site features with total station and levelling data was collected using auto level. The GTS bench mark was transferred to the site by carrying out fly levelling and the bench marks were established at site. Entire levelling was carried out using GTS bench mark.

The following features were collected during survey:

- Existing road pavement surface, is variation in width along with all other relevant road details like centreline of carriageway, pavement edge, embankment/cutting edges top and bottom, side drains, signs, km posts etc.
- Location of traffic islands, median, police chowks, within limits of ROW.
- All religious places – churches, Towers, Parks, and Heritage Buildings etc., including location, building lines and clear dimensions of compound walls and extensions.
- Trees (position, species and girth measured 1.2m from ground level) Tree Species and type of crops.
- Building fronts and outlines (to be classified by construction type i.e. RCC/tiled house/thatched house etc with number of storey).
- Electric transformers, mast, tower, etc.
- All utilities such as telephonic line, BESCOM lines, water pipe control point chamber, sewage manholes which are above the ground.

Levels along the alignment were taken at every 20m intervals and at all intermediate breaks along the centre line of the existing alignment. Spot levels were recorded at critical points such as horizontal curve start, centre and end points and vertical curve start, centre and end points.

Cross sections, covering drain to drain on either side of service road or compound to compound or building line which ever was more, were taken at intervals of 20m in

general with levels at 5 m c/c. Cross sections were taken at the centre line of all culverts and at all critical points, mentioned earlier. The coordinates of X,Y Z are taken w.r.t GPS coordinate connecting the GPS coordinates observed using DGPS.

Details of the topographical survey are shown in drawing NC/Topo/01 which is enclosed along with drawings volume.

4.8 Traffic Survey

3.8.1 Project Background

Traffic studies are the initial step of any road project whether it is improvement/upgradation over existing road. This generally considered by way augmentation of existing capacity of road such that, the road would handle the present and future traffic in acceptable level of service. In order to decide upon the type of improvement or upgradation required needs some base line studies related to traffic volume and its composition. These traffic studies are the base for deciding many components such as roadway width, lane width, pavement design etc. All these signify the importance of traffic data. Traffic flow on rural section is different when it is compared with that of an urban road section. In the urban areas, the traffic flow is frequently interrupted with close intersections and continuous ribbon development. When there is a ribbon development is majorly a commercial establishment, this will also affect the through traffic along the corridor due to parking or stopping near commercial establishment. All these conditions warrant for congestion and delay in the traffic flow thereby increase in the travel time leading to unnecessary increase in Vehicle Operation Cost. Presently, the study is under consideration is pertaining to an urban section of an important arterial road in the Bangalore City which has similar type of ground condition and carry maximum volume of passenger vehicles specially Two-Wheelers, Autos and Cars. The proposed project road forms a critical link within the Central part of Bengaluru city. It covers a stretch of –

Proposed Elevated corridor from Sholey Junction to St. John Hospital junction along Hosur Road.

4.5.2 TRAFFIC SURVEY LOCATIONS

Classified traffic volume count was carried out at location shown in below sketch –

The following survey locations were selected for the traffic surveys and the schedule of traffic surveys is presented below. The following **Table 4.5.1**gives details of various traffic surveys conducted with period of survey.

Table 4.5.1 Schedule of Traffic Surveys

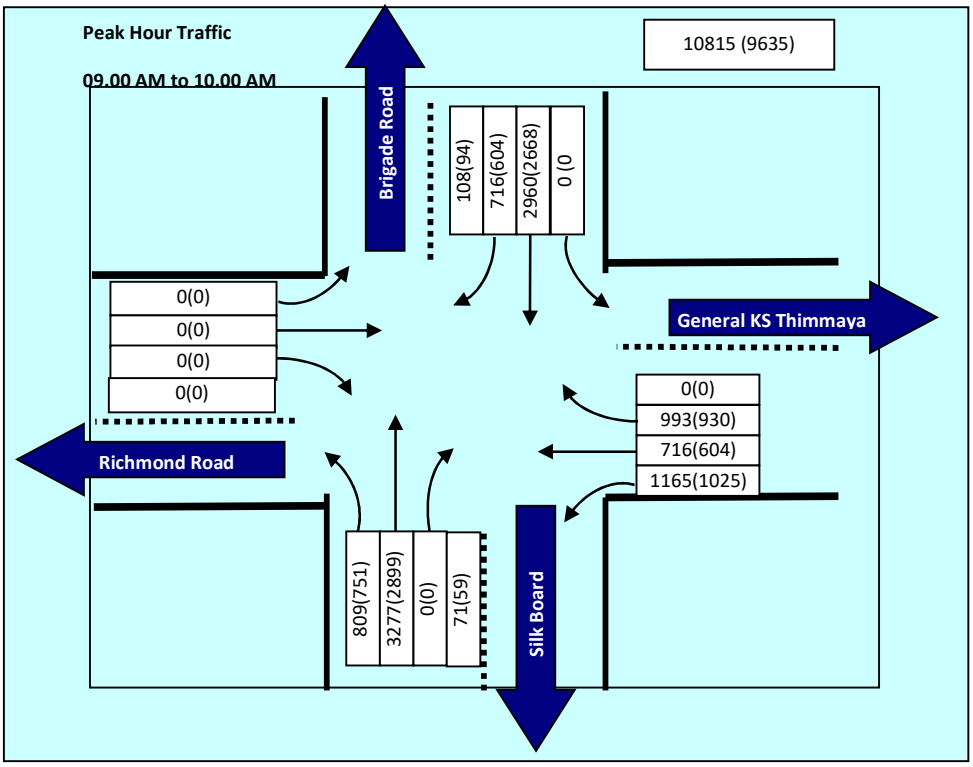
Sl. No.	Type of Survey	Duration	Location	Date(s) of Survey
1	Turning Movement Surveys	24 Hrs	Shooley Junction	18.10.2025
2		24 Hrs	Adugodi Junction	

Sl. No.	Type of Survey	Duration	Location	Date(s) of Survey
3		24 Hrs	St John's Hospital Junction	
1	Origin-Destination Survey	Peak Hours	Adugodi Junction	
3		Peak Hours	St John's Hospital Junction	

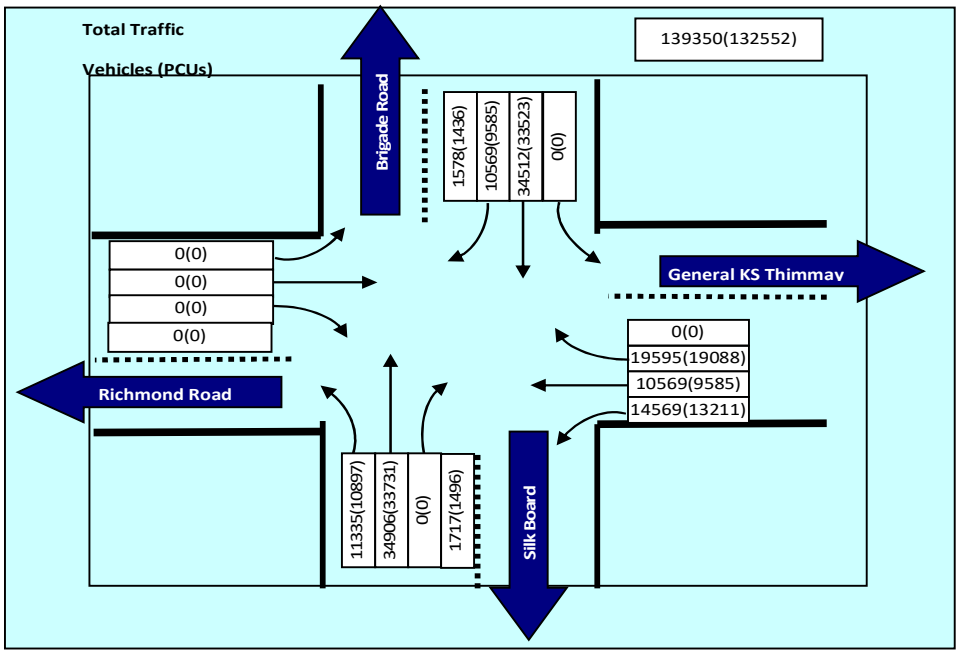
3.8.2 TURNING MOVEMENT COUNT SURVEYS

The surveys were conducted for one day (24 Hours covering morning and evening peak hours) to obtain classified turning movement at the identified junctions. The data derived from the survey will be analyzed to identify requirements of suitable remedial measures, such as construction of grade-separated intersections.

3.8.3 TMC 01 (Shooley Junction)

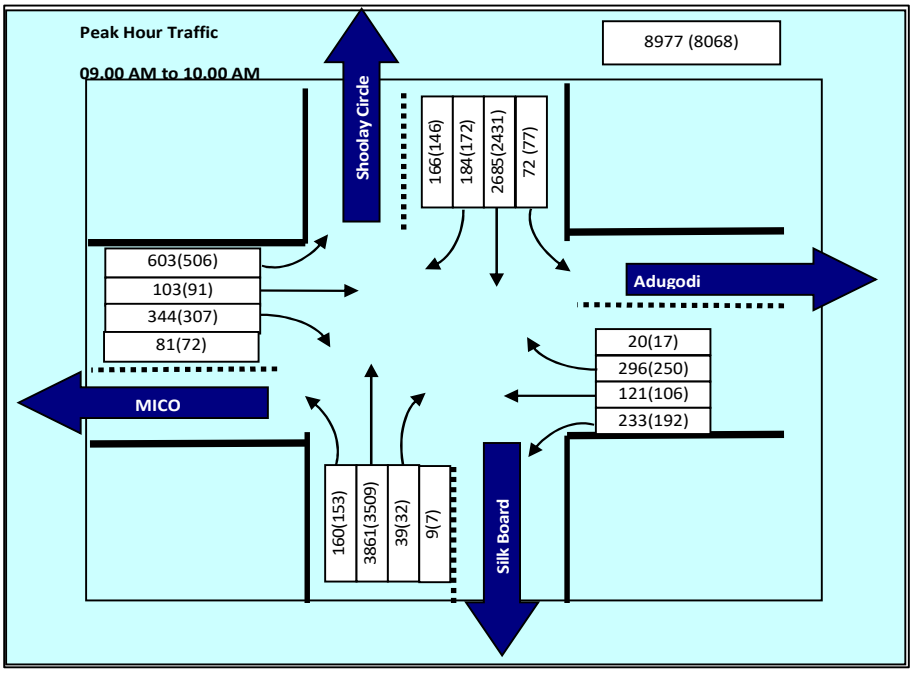


Peak Hour Traffic at Shooley Junction

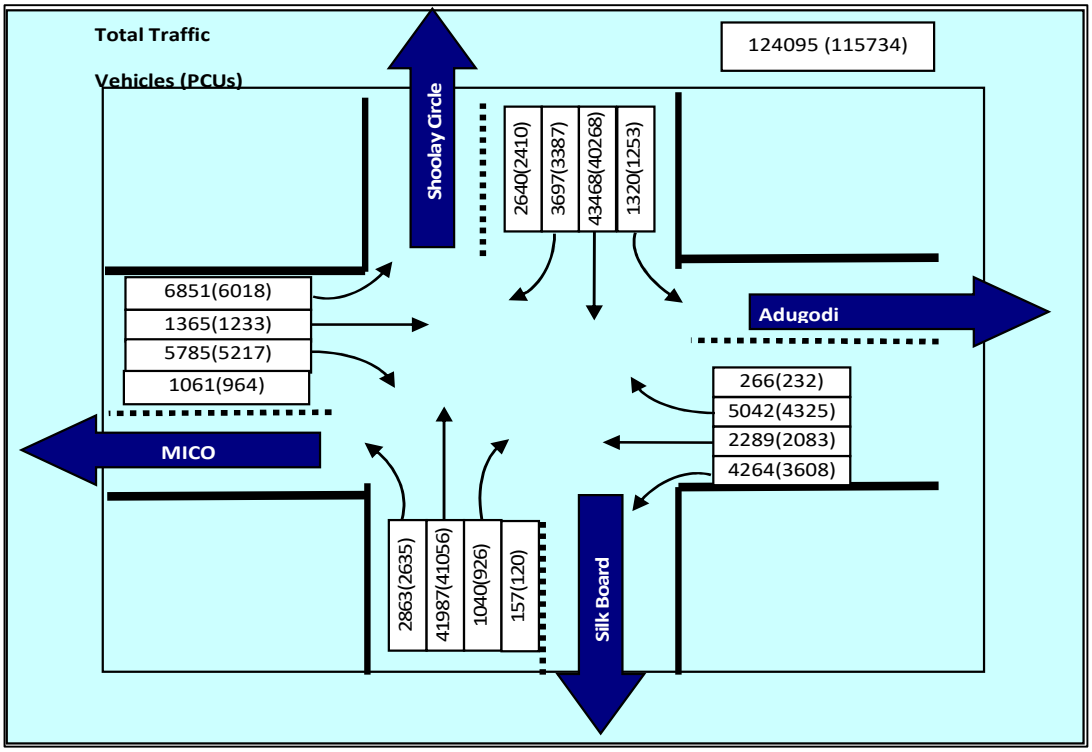


Total Traffic at Shooley Junction

3.8.4 TMC 02 (Adugodi Junction)

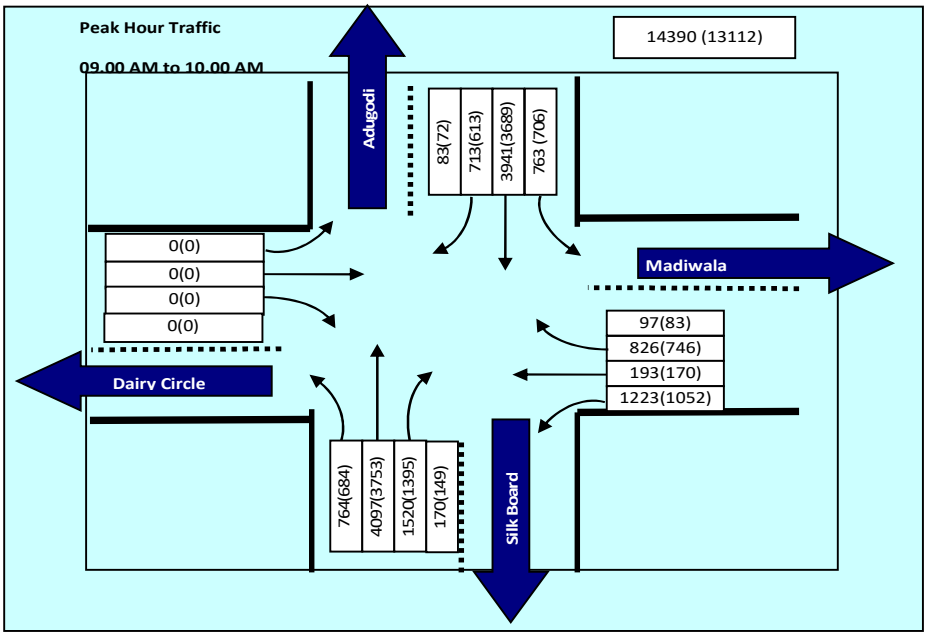


Peak Hour Traffic at Adugodi Junction

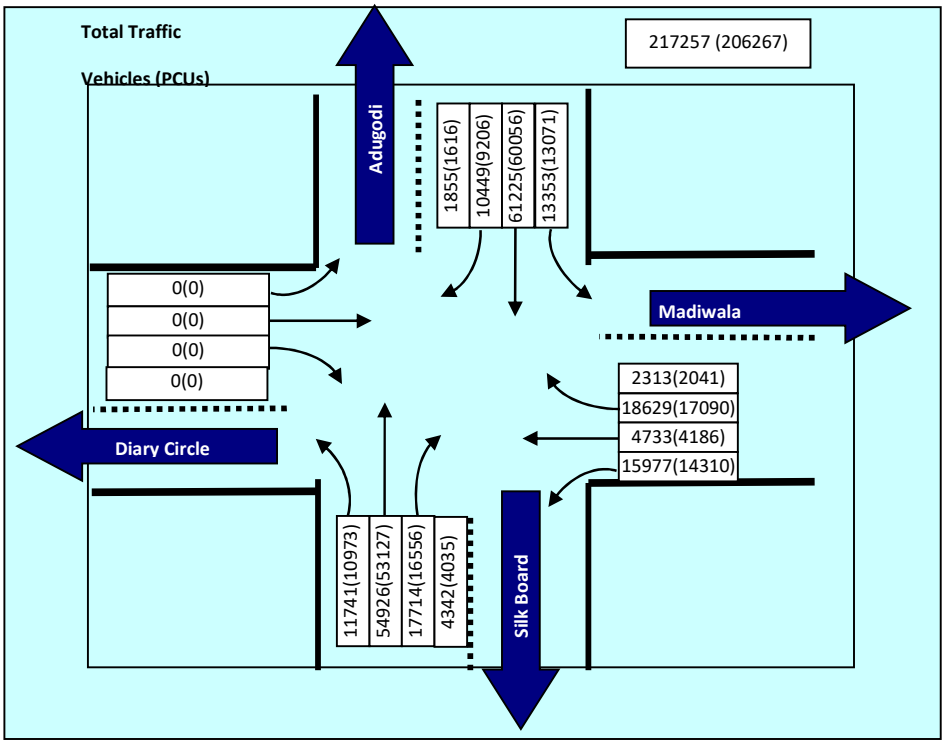


Total Traffic at Adugodi Junction

3.8.5 TMC 03 (St John's Hospital Junction)



Peak Hour Traffic at St John's Hospital Junction



Total Traffic at St John's Hospital Junction

3.8.6 Justification/warrants for grade separators or interchanges

As per clause 5.10.4 of IRC: SP: 90-2010 and as per clause 4.5.6 of IRC: 92-2017, Grade Separators or Interchanges, in general, are expensive to construct and a major factor influencing the cost is the type of arrangement made for the various traffic movement. The arrangement may range from separating only one traffic movement from other to the complete separation of each traffic movement from every other movement, so that only merging and diverging movements remain. Similarly, the vehicle operating cost will vary depending on the type of ramp arrangement, from direct conflict-free connections to indirect connections involving extra travel distance. However, the following points may be helpful in guiding the choice of an interchange at the preliminary planning stage:

1. Interchanges will be required at all major crossings on highways developed to expressway standards.
2. An interchange may be justified at the crossing of a major arterial road with another road of similar category carrying heavy traffic.
3. An interchange may be justified when an at grade intersection fails to handle the volume of traffic resulting in serious congestion and frequent choking of the inter-section. This situation may arise when the total traffic of all the arms of the intersection is in excess of 10,000 PCU's per hour.
4. High and disproportionate rate of fatal and major accidents at an interaction not found to respond to other traffic control or improvement measure may warrant an interchange.
5. In some situations, the topography is such that interchanges are the only type that can be constructed economically.
6. The requirement of interchange may also be justified from the existing constraints of the junctions other than traffic volume like parking, market, important and religious structures, buildings with frequent crowding.
7. While planning interchange at a particular location the traffic requirements of the entire road on both sides should be taken into account.

3.8.7 SHOOLEY JUNCTION

The Shooley junction is formed by 3 roads, Hosur Road, General K S Thimmayya Road and Richmond Road. The present peak hour capacity of the junction is **9635 PCUs per Hour**. This junction exceeds **10,000 PCUs** per Hour in year **2026** which warrants for grade separation as per clause 5.10.4 of IRC: SP: 92-2010 and as per clause 4.5.6 of IRC: 92-2017.

Peak Hour traffic details for Shooley Junction

Peak Hour	Total	YEARS											
		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Morning	Vehicles	10815	**11601**	12444	13349	14319	15360	16477	17674	18959	20337	21816	23401
	PCUs	9635	**10335**	11087	11893	12757	13684	14679	15746	16891	18118	19435	20848

Evening	**Vehicles**	8599	**9112**	9656	10232	10842	11489	12175	12901	13671	14486	15351	16267
	PCUs	7909	**8380**	8880	9410	9972	10567	11197	11865	12573	13323	14118	14960

3.8.8 **Adugodi Junction**

The Adugodi junction is formed by 3 roads, Hosur Road, New MICO Road and Adugodi Road. The present peak hour capacity of the junction is **7701 PCUs per** This junction exceeds **10,000 PCUs** per Hour in year **2029** the capacity which warrants for grade separation as per clause 5.10.4 of IRC: SP: 92-2010 and as per clause 4.5.6 of IRC: 92-2017.

Peak Hour traffic details for Adugodi Junction

Peak Hour	**Total**	**YEARS**											
		2025	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
Morning	**Vehicles**	8977	9603	10272	10988	**11754**	12574	13450	14388	15390	16463	17611	18839
	PCUs	8068	8630	9231	9875	**10563**	11300	12087	12930	13831	14795	15827	16930
Evening	**Vehicles**	7738	8212	8715	9249	**9816**	10417	11055	11733	12451	13214	14024	14883
	PCUs	7090	7525	7986	8475	**8994**	9545	10130	10751	11409	12108	12850	13638

3.8.9 **St John's Hospital Junction**

The St John's Hospital junction is the major junction at the Hosur road. The present peak hour capacity of the junction is **13112 PCUs per Hour** which is more than **10,000 PCUs** per Hour which warrants for grade separation as per clause 5.10.4 of IRC: SP: 92-2010 and as per clause 4.5.6 of IRC: 92-2017.

Peak Hour traffic details for St John's Hospital Junction

Peak Hour	**Total**	**YEARS**											
		2025	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
Morning	**Vehicles**	**14390**	15305	16278	17312	18413	19583	20828	22152	23560	25058	26651	28345
	PCUs	**13112**	13946	14832	15775	16778	17844	18979	20185	21468	22833	24284	25828
Evening	**Vehicles**	**13252**	14030	14854	15725	16649	17626	18661	19756	20916	22144	23443	24820
	PCUs	**12108**	12819	13572	14368	15212	16105	17050	18051	19111	20233	21420	22678

As per the above traffic data, the traffic at most junctions exceeded the capacity which warrants for grade separator facility or will exceed within the next 3 years and become bottleneck in near future. This indicates the requirement of alternative solutions to overcome this problem in terms of grade separators at the junctions.

3.8.10 Traffic on Proposed Elevated Corridor

Vehicle Type	Through - 01			Ramp - 01			Through - 02		
	Existing	Grade Separator	At Grade	Existing	Grade Separator	At Grade	Existing	Grade Separator	At Grade
	Adugodi - Silk Board			Adugodi - Madiwala			Silk Board- Adugodi		
2 Wheeler	2351	1234	1117	370	147	223	2412	1266	1146
Auto Rickshaw	425	224	201	97	25	72	446	235	211
Car/ Jeep/ Van	853	396	457	258	66	192	994	461	533
Mini Bus	8	1	7	2	0	2	11	2	9
Std. Bus	150	30	120	0	0	0	93	18	75
LCV	143	19	124	34	3	31	128	17	111
2 Axle	0	0	0	1	0	1	1	0	1
3 Axle	4	0	4	0	0	0	0	0	0
MAV	0	0	0	0	0	0	0	0	0
Tractor with Trailer	2	0	2	0	0	0	2	0	2
Tractor without Trailer	3	0	3	1	0	1	1	0	1
Cycle	2	0	2	0	0	0	9	0	9
Cycle Rickshaw	0	0	0	0	0	0	0	0	0
Bullock Cart	0	0	0	0	0	0	0	0	0
Horse	0	0	0	0	0	0	0	0	0
Other (Special)	0	0	0	0	0	0	0	0	0

3.8.11 Forecasted Traffic and V/C Ratio Calculation with remarks for Through Traffic

SL No	Description	Traffic Volume				C.W. Width	Capacity	V/C Ratio			Remarks
		Traffic 2025	Traffic 2028	Traffic 2038	Traffic 2048			2028	2038	2048	
Shooley Junction Grade Separator											
1	Through (Brigade Road-Silk Board)	848	982	1600	2606	11.5	3600	0.579	0.943	1.536	V/C>1 in 2039
2	Through-(Silk Board-Brigade Road)	951	1101	1794	2922						
St. John's Hospital Junction Grade Separator											
3	Through-1 (Adugodi-Silk Board)	1685	1950	3177	5175	7.5	2700	0.722	1.177	1.917	V/C>1 in 2035
4	Ramp-1 (Adugodi-Madiwala)	212	245	399	650	7.5	2700	0.091	0.148	0.241	V/C<1
5	Through-2 (Silk Board-Adugodi)	1761	2038	3320	5408	7.5	2700	0.755	1.230	2.003	V/C>1 in 2034
Adugodi Junction Grade Separator approach											
6	Through-1 + Ramp-1	1897	2195	3576	5825	7.5	2700	0.813	1.324	2.157	V/C>1 in 2032
7	Through-2	1761	2038	3320	5408	7.5	2700	0.755	1.230	2.003	V/C>1 in 2034

3.8.12 CONCLUSION

The turning movement results obtained for all junctions on Hosur road show that the capacity of most of the junctions already exceeded the design capacity of junction (10000 PCUs per Hour) which requires immediate intervention to avoid bottlenecks or congestion at the junctions. This can be done either by making changes to policy (modal shifts and promoting use of public transport) or by construction of grade separators at each junction. Also, there are other junctions along the corridor, mainly, Anepalya road junction, Koramangala and Forum road junctions. There are totally 5 junctions within 4.2 Km stretch and stand alone fly overs at all junctions will create roller coaster effect for the road users. Also, few junctions are closely spaced, requiring combining of junctions, Hence,

it requires elevated road along the corridor, segregating through traffic, so that conflicts along these junctions are minimized.

4.9 SOIL INVESTIGATION

Geo - technical investigations were carried out along the corridor to understand the soil strata through exploratory borings.

Following guidelines used to carry out geo tech investigation-

- IS: 1892 – 1979: CODE OF PRACTICE FOR SUB-SURFACE INVESTIGATION FOR FOUNDATIONS, and
- The specifications given in Clause 1102.1 of SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (Fifth Edition)

Summary and Recommendation are presented below –

- Given the heavy superstructure loads anticipated, deep foundations are recommended. Bored cast-in-situ reinforced concrete piles of 1.35 m diameter shall be adopted in accordance with IS 2911 (Part 1/Sec 2) and IRC:78/IRC:112, using site-specific geotechnical data and confirmed groundwater conditions.
- Each pile shall be founded in rock with the following socketing requirements, whichever is met earlier: (i) socket ≥ 3D(≈ 4.05 m) into dense weathered rock/refusal stratum with SPT-N > 100, or (ii) socket ≥ 1D (≈ 1.35 m) into hard rock with core recovery CR > 30%. The target average pile length is 15 m, subject to confirmation during construction by drilling logs and on-site test results.
- Ultimate axial and lateral capacities shall be evaluated using appropriate rock socket parameters (end bearing and side shear) derived from site investigation and, where feasible, instrumented load tests. Adopt factors of safety as per IS 2911/IRC depending on test evidence (typically FOS 2.5 for axial compression from static tests, higher if inferred)

The details of soil investigations are enclosed as Annexure -2.

4.10 Roadside Investigations

Preparation of road inventory of the project road was undertaken first. The purpose of the survey was to obtain the necessary information regarding the road features along the project road, condition and performance of drainage structures and other ancillary road features like footpath, median, kerbs etc. An integrated program to carry out surveys and investigations were developed, using IRC SP -19 as a general guide.

The following information was collected as part of the survey.

- Carriageway width
- Shoulder widths
- Surface type for carriageway and shoulders
- Embankment or cut and approximate height
- Location, type and condition of side drains
- Location and type of road access and roadside features (parking bays, bus stops, and all major and minor commercial establishments)
- Roadside land use (agriculture, barren, built-up. slum areas, urban)
- Presence of crossing traffic (vehicular, pedestrian).

CHAPTER- 5 – PLANNING AND DESIGN CRITERIA

5.1 Planning for Elevated Corridor

One or combination of the following usually guides planning of elevated corridor in urban areas:

- Elimination of conflicting traffic streams of traffic.
- Hierarchy of the intersecting roads.
- Intersection traffic characteristics.
- Present development level and proposed development pattern for the influence area.
- Lack of alternative routes / modes.
- Feasibility with respect to available space and minimum land acquisition.
- Utilities present at the project location, feasibility of shifting / relocation.
- Other major infrastructure projects planned.
- Cost and Economic considerations.
- Traffic diversions and management during construction.

5.2 Planning Criteria

The following paragraphs briefly highlight the various Design considerations and standards used for the present proposal. However, it is important that the preamble to Design criteria are clearly understood in the context of urban development –especially with due consideration to traffic, existing road network, development pattern, tight of way, rise and fall of road etc.

The Indian Roads Congress and the Ministry of Surface Transport and Highways specify various guidelines and specifications for flyovers, junctions and other facilities pertaining to flyovers. These specifications are largely based on the theoretical considerations and ideal situations which can hardly be obtained in urban situation for a city like the present

one. Hence, in the present proposal, certain changes and modifications in the Design standards are reviewed keeping in view the site constraints.

5.3 Design Standards - Roads

Design standards for the Design of Horizontal and Vertical Geometry and other road elements are used referring following guidelines of latest Indian Roads Congress:

IRC: SP 90

IRC: 86

IRC: SP 92

IRC: 73

5.4 Design standards considered are briefly stated below.

5.4.1 Geometry

The horizontal geometry will be designed in accordance with Clause 10 of IRC:86-2018. Following considerations are made in horizontal geometry design

- Minimum disturbance to existing structures which are already constructed based on inputs from B SMILE in various meetings / discussions.
- To maintain existing road horizontal profile to the extent possible.
- Road widening considering building lines on either side of existing carriageway.
- Rise and fall of existing road in design of the facility;

5.4.2 Design Speed

The design speed for elevated road/grade separator in urban stretch is generally governed by the existing road plan and building lines. The most critical sections governing the design speed is the turning movement of vehicles on curves and available sight distance to traffic approaching the junction. Considering above factors, design speed of 60 Kmph is adopted

in general, except at Down Ramp, sharp turnings and at exceptional locations where site constrains, minimum speed of 40 Kmph is followed.

These constrained locations are considered in alignment design considering ground constraints like building lines, land acquisition and utilities.

5.4.3 Horizontal Alignment

Horizontal alignment for the grade separator is designed in accordance with IRC:38-1988 "Guidelines of Design of Horizontal Curves for Highways and Design Tables". Clause 10.3 of IRC:86-2018 specifies minimum curve radius of horizontal curve for 60 Kmph as 70m for 4% super-elevation. These guidelines will be followed for reasonably flat and less winding alignments. Depending on site constraints modifications are made for providing tighter curve radius wherever required based on site specific considerations. For ramps, curve radius corresponding to 40 Kmph design speed is proposed.

5.4.4 Super Elevation on Curves

Super-elevation on horizontal curves will be attained as per IRC: 38-1988. The super elevation will be limited to 4 % as per CI 10.2 of IRC:86-2018 as the project area is in urban section.

5.4.5 Cross-Sectional Elements of Elevated Corridor

Width of grade separator has a direct relationship with the traffic volume it is expected to serve and width available at ground level based on land acquisition. Widths of flyovers / grade separator for various categories are as shown in below table

Table 5.4.5 Cross Sectional Elements of Deck

Lane Type	Carriageway Width	Kerb & Crash Barrier	Total Width (m)
Main Flyover along Hosur road from St. john to Anepalya junction- 4Lane (Two-way Bi- Direction)	2 x 7.5 m	0.5m x 2 sides + 1.2m Median	17.2m

Main Flyover at Shooley junction- 3Lane (Two-way Bi- Direction)	11 m	0.5m x 2 sides	12m
Entry Ramp - 2 lane Unidirectional at Sarjapura Road	6.0m	0.5m x 2 sides	7.0m

5.4.6 Surface Level Road

The surface level road will carry local remaining traffic (traffic using shops and commercial establishment, cross road). The width of surface level road will depend on the traffic at the surface level after the flyover is constructed and majorly on space availability in urban roads. However, approaches to fly over is mostly at the footpath locations with land acquisition and existing traffic pattern at grade will not be altered. A minimum of 5.5m carriageway at surface level along with 1.5m Drain cum footpath is maintained at all location.

5.4.7 Cross Slope

The deck and approaches is proposed with 2.5% cross slope.

5.4.8 Vertical Alignment

The vertical geometry of the flyover / underpass is designed as per guidelines given in IRC: 92-1985. Clause 5.1.2 of IRC: 92-1985 states that the vertical gradient should be desirably kept at 4%, but in no case exceed 6%. Vertical curves are provided at locations of change in gradient. The length of vertical curves is dependent on change in grade between two vertical straight and this will be as per IRC SP: 23-1993 "Vertical Curves for Highways".

5.4.9 Approach Ramp

It is proposed to adopt "Reinforced Earth" type retaining structure for the approach ramp. The reinforced earth facia wall made of precast concrete panels offers great scope for a

variety of aesthetic treatments in the form of panel shapes and colour. Apart from aesthetics, it improves the speed of construction.

Approach gradient of grade separator is primarily dictated by the following.

- Space available in the approach road
- Distance available to nearest major intersection.
- Access for cross roads, bus stops or other important buildings.

Clause 11 of IRC: 86-2018 specifies that the maximum vertical grade in urban area should be limited to 1 in 25. Approach longitudinal gradient of 1 in 30 will generally be attempted for surface level roads to account for the mixed form of traffic present in the city. However, considering the project location, type of vehicles (Majority of 2 Wheelers and 4 Wheelers) ramp of 1 in 20 is proposed as per the discussion with B SMILE to minimise the cost of construction and cost of land acquisition

However, in situations, where the ramp length needs to be curtailed due to proximity of adjacent intersection or similar cases, the slope might require to be restricted.

5.4.10 Design loads For Structure

- **Dead Loads**

Self-weight = 25 kN/m^3

Crash Barrier = 7.75 kN/m

Wearing Coat = 2 kN/m^2

- **Vehicular Live loads**

The design is carried out for IRC vehicular live loads as per IRC 6:2017 corresponding to various traffic lanes i.e Intermediate Lane (5.5m carriageway), 2 Lane (7.5m carriageway), 2 Lane with paved shoulder (11m carriageway), 4 Lane Bi-directional carriageways (2 x 7.5m).

Impact factor considered as per IRC-6-2017, corresponding to Class A & Class 70R

Vehicle.

- **Wind forces**

Wind forces have been considered as per IRC: 6 – 2017 and subsequent amendments in the latest edition of Indian Highways.

The appropriate wind force on Superstructure and substructure are considered as per CL 209 IRC 6 : 2017 with a basic wind speed of 33m/s corresponding to Bangalore location.

- **Seismic force**

The structure has been designed for the seismic force as per the provisions of IRC-6-2017, corresponding to seismic zone – 2.

- **Temperature range**

i) For design of structure to account for temperature in formula, $(\Delta L) = \alpha$ Lt,

The value of T shall be (+/-) 29.55/25.55 degree centigrade.

Where α = Coefficient of expansion or contraction = 1.2×10^{-5}

L = Length of the member

(ΔL) = Expansion / Contraction due to temperature variation in appropriate units.

ii) The super-structure is also designed for effects of distribution of temperature across the deck depth.

Vehicle Collision Load:

It is proposed to provide suitable fencing system taking in to account its flexibility having a minimum height of 1.50m above the grade level carriage way and according the piers are designed for residual load component, with vehicles plying with speed limit of 30 Kmph as the road at grade are city roads, as per art 225.3.1, IRC: 6-2017.

- **Braking Force**

Braking Force is considered as per CL 211.2, IRC:6-2017. The horizontal load will be fraction of vertical reactions as per the guide lines of CL 211.2.

- **Friction Force**

Friction force is considered as per CL 211.50 IRC: 6 -2017

- **Centrifugal Force**

Centrifugal force will be as per CL 212 IRC: 6 -2017

- **Active Earth Pressure**

Active Earth Pressure will be as per CL 214.1.1 IRC: 6 -2017

- **Live Load Surcharge**

Live Load Surcharge will be as per CL 214.1.1.3 IRC: 6 -2017

5.4.11 Design Basis – Structure

5.4.12 Super Structure.

SL NO	DETAIL	DESCRIPTION
General Arrangements		
1.	Span Arrangement	50.0m for standard viaduct spans, except for adjustable spans of 47.7m, 40m,30m, 22.5m, 20.75m.
2	Expansion Joints	Expansion joints are proposed at every span.
2.	Carriage way	2 x 2-Lane carriageway for main arm from Madiwala to Anepalya Junction. Four lane divided carriageway for main arm for the remaining length of elevated corridor Three lane carriageways at stand alone flyover at Shooley junction.
3.	Crash Barrier / Median	RCC Crash Barrier on either side and central 1200mm wide RC median with W beam barriers
4.	Overall width of deck.	17.20m for main arm.
5.	Type of superstructure.	**Fish belly type Box Girder composite UHPFRC and HPC for standard spans of various deck width for elevated corridor/flyovers.**
6.	Overall depth of superstructure.	2.1 to 2.4m depth.
7.	Minimum thickness of deck slab.	250mm.
8.	Cross Drainage	2.5% camber in straight with drainage spouts at the end of carriageway with down take pipes to

		convey the way to grade level drains.
9.	Wearing Coat	Bituminous Concrete uniform thickness 50mm in single layer on 4mm thick mastic pad.
10.	Noise Barrier	Noise Barriers proposed along the project road for site face properties.
Loads considered in designs.		
1.	Dead Load	25 kN/m^3 for RCC 22 kN/m^3 for asphaltic wearing coat.
2.	Superstructure live load.	Superstructure designed for IRC:70R & Class 'A' Vehicle
3.	Load combination	DL + SDL + VhLL.

Material adopted.		
		Steel – Fe550 for all structures Low Relaxation Class 2 Strands are proposed For Pre-stress steel <u>Superstructure</u> <u>For Main arm, Entry and Exit Ramps</u> **UHPFRC – M150 for U-Trough** HPC M50 for deck slab and end diaphragm <u>Substructure</u> M50 for Pier and Pier Cap M35 for Pile and Pile Cap M35 for Open Foundation. Crash Barriers are in M40 Grade Concrete.
Permissible stresses:		
1	In Concrete – Flexural	IRC 112-2020 (CL 12.2)
2	Permissible Tensile stresses in case of PSC	As per IRC 112-2020 (CL 12.1) at locations other than segment joints

	Under Transfer Condition	
	Under Service Condition, with Frequent Combination As per Table B.3 of IRC 6-2017 (column 3)	As per IRC SP 65 - 2018 (CL 3.2) at segment joints
	Under Service Condition with Rare Combination As per Table B.3 of IRC 6-2017 (column 2)	As per IRC SP 65 - 2018 (CL 3.2) at segment joints
3	Crack Width	As per IRC: 112-2020 (Cl:12.3.4)
4	Flexural Tension	As per Table 6.5 IRC 112-2020
5	Modulus of Elasticity, Ec	As per Table 6.5 IRC 112-2020
6	Permissible Direct Compressive Stress	As per IRC-112 (Cl:12.2.1)
7	Maximum permissible shear stress	As per IRC-112 - 2020(Cl:10.3.2 and 10.3.3)
8	Permissible shear stress without shear reinforcement.	As per IRC-112 - 2020 (Cl:10.3.2)
9	Elastic Modulas of Steel	As per IRC-112 - 2020 (Cl:6.2.2)
F	Structural Design	
1	Design will be carried out by limit state method as per IRC-112	
G	**Expansion joint:**	
I	Slab Seal type as per MOST/IRC specifications, also conforming to recent amendments of MoSRT&H, Transport Bhawan, New Delhi.	
H	**Bearing Data**	
I	Type of bearing	POT Cum PTFE/Spherical bearings conforming to IRC 83: (part III/IV), also conforming to recent amendments of MoSRT&H, Transport Bhawan, New Delhi.
I	**General Design Requirements Provided**	
1	Minimum clear cover for any reinforcement	40mm for super structure 75mm for foundation
	Concrete Cover to Post tensioned	75mm

	ducts	
2	Minimum tensile reinforcement in beams	As per IRC:112-2020 (Cl:16.5.1.1)
3	Minimum shear reinforcement	As per IRC-112 - 2020 (Cl:16.5.2)
4	Minimum and Maximum reinforcement bar sizes	As per IRC-112 - 2020 (Cl:15.5.2.2)
5	Reinforcement bar spacing	As per IRC-112 - 2020 (Cl:15.2.1)

5.4.13 Substructure.

Substructure system.		
Load considered in design.		
1.	Dead loads from superstructure – (G1)	
2.	Superstructure imposed loads from superstructure – (G2)	
3.	Vehicular live load from superstructure – (G3).	
4.	Self Wt of pier system – (G4)	
5.	Braking load from vehicular traffic – (fb)	
6.	Wind loads	As per IRC – 6-2017 for wind speed of 33m /sec.
7.	Seismic effects	FeQ. Zone factor – 0.10 Damping – 5%. Importance factor – 1.2.

5.4.14 Foundation.

SL NO.	DETAILS	DESCRIPTION

Foundation system.		Open / Pile Foundation with Bored Cast in situ Piles as per relevant Codal Practice
Loads considered in design		
1.	Dead loads from superstructure – (G1)	
2.	Superstructure imposed loads from superstructure – (G2)	
3.	Vehicular live load from superstructure – (G3).	
4.	Self Wt of pier system – (G4)	
5.	Self Wt of foundation - (G5)	
6.	Braking load from vehicular traffic – (fb)	
7.	Wind loads	As per IRC – 6-2017 for wind speed of 33m /sec.
8.	Seismic effects	FeQ. Zone factor – 0.10 Damping – 2%. Importance factor – 1.2.
material adopted		M50, M35 grade of concrete, Fe550 grade steel & Low Relaxation Class 2 Strands are proposed For Pre-stress steel
Limiting stresses		
1.	In concrete flexural compression.	16.8 Mpa for M35 concrete as per IRC- 112 2020
2.	Allowable stress in Steel	440 Mpa for Fe 550 steel as per IRC – 112-2020
Limit State Design is Adopted for foundation As per IRC- 112. Load Combinations as per IRC:6 2017, Table B 3.1 to B 3.3		

5.4.15 General Design Criteria

	general design criteria's	
1.	Maximum pile capacity (Vertical, Horizontal and Uplift) are as per Geotech report and increase in pile load for wind & earth quake considered as per IRC – 78-2014	
2.	Clear cover for reinforcement	75mm.

5.4.16 Pavement Design:

The flexible pavement is designed as per IRC:37-2018 for a cumulative design traffic of 30 MSA and a subgrade soaked CBR = 8% (reliability, lane distribution and growth assumptions as per code). Shoulder and drainage provisions are compatible with the main carriageway to preserve the design life.

Pavement crust: - proposed curst details

Bituminous Concrete (BC): 40 mm

Dense Bituminous Macadam (DBM): 95 mm

Wet Mix Macadam (WMM): 250 mm

Granular Sub-Base (GSB): 200 mm

Prepared Subgrade: 500 mm

5.4.17 Overlay

An asphalt overlay is proposed over the existing carriageway to restore structural capacity and riding quality. The design follows IRC practice for overlays on flexible pavements.

Bituminous Concrete (BC): 40 mm
Profile correction Course Dense Bituminous Macadam (DBM): 60 mm

5.4.18 Reference Codes

- IRC:37-2018 "Guidelines for Design of Flexible Pavements"
- IRC: 86-2018 "Geometric Design Standards for Urban Roads and Streets"
- IRC: 92-2017 "Guidelines for the Design of Interchanges in Urban Areas"
- IRC: 106-1990 "Guidelines for Capacity of Urban Roads in Plain Areas"
- IRC: 5 – 2015: Specifications and Code of Practice for Road Bridges (Section-I)
- IRC: 6 – 2017: Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations.
- IRC: 112 – 2020: Code of Practice for concrete Road Bridges
- IRC: 78-2024 Part 1: Standard Specifications and Code of Practice for Road Bridges, Foundation and Substructure.
- IRC: 78-2020 Part 2: Code of practice for limit state of design of foundations
- IS: 456 - 2000 Code of Practice for Plain and Reinforced Concrete
- IS: 2911 (Part I/Sec 2) - 2010 Code of Practice for Design and Construction of Pile Foundations
- IRC: 83 (Part - III) and Part IV: Code of Practice for Road Bridges-Section IX – POT cum PTFE Bearings and Spherical Bearings
- IRC: Sp-65 - 2018: Guidelines for Design and Construction of Segmental Bridges
- **NF P 18-470 – 2016: Concrete — Ultra-high-performance fibre-reinforced concrete — Specifications, performance, production and conformity**
- **NF P 18-710 – 2016: National addition to Eurocode 2 — Design of concrete structures: specific rules for Ultra-High-Performance Fibre-Reinforced Concrete (UHPFRC)**
- IRC SP-50 – 2012: For drainage Design
- SP 16 – 2019 Guidelines on Measuring Road Roughness and Norms
- IRC: 35 - 2015 for Road Marking
- IRC: 65- 2017: Guidelines for Planning and Design of Roundabouts for Road Signages

CHAPTER- 6– ALINGMENT

6.1 General

After review of Traffic data available, its shows that the intersection remains congested for considerable duration of the day. The volume of traffic is expected to increase, as a result of which congestion and delays at the junction increases. This would further lead to increased level of pollution and accidents. It is the right time for taking up necessary measures to reduce the congestion at the intersection by enhancing the capacity/ reducing conflicts and delays at the junction in order to avoid future traffic problems. The capacity of an intersection can be increased by segregating major conflicting traffic movements and segregation of traffic can be achieved by the construction of grade separators.

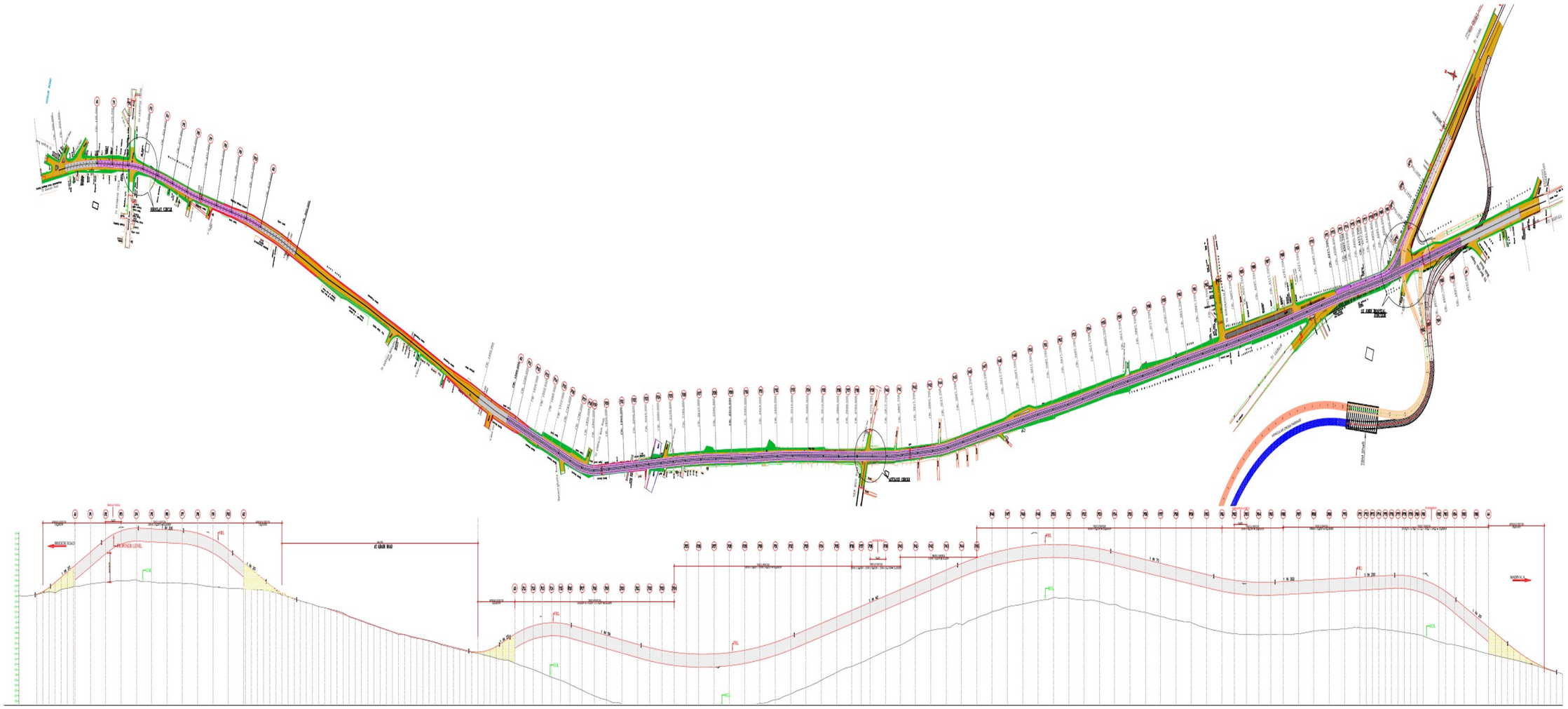
6.2 Constraints at Site

The following constraints were kept in mind while deciding on the alignment options for improving traffic circulation along Hosur Road from Shooley Junction to St. John Hospital Junction –

- There are commercial Establishments on either side of the road.
- St. John Hospital at St. John signal.
- Heavy movement of commercial vehicle.
- BMRCL Tunnel metro crosses alignment at Anepalya Junction.
- No service road exists along corridor to divert vehicle movement.

6.3 ALIGNMENT

4-LANE BI-DIRECTIONAL ELEVATED CORRIDOR ALONG HOSUR ROAD FOR THROUGH TRAFFIC FROM MADIWALA JUNCTION TO ANEPALYA JUNCTION AND STANDALONE FLYOVER AT SHOOLEY JUNCTION ALONG HOSUR ROAD.



6.4 Advantages

- Vehicles from Silk board / Hosur Road can directly use the elevated corridor to reach MG Road/Brigade Road/Bangalore Central, north and eastern side of Bangalore without any traffic signal.
- The corridor allows smooth movement from Madiwala to Shooley junction and vice versa without traffic signals, ensuring faster travel time.
- Through traffic will be diverted onto the elevated corridor, reducing the load on the existing Hosur Main Road.
- With a portion of traffic shifted to the elevated corridor, the at-grade road will get relief from heavy congestion, especially during peak hours.
- Elevated road will reduce the traffic on at grade road which is advantageous for public transport especially BMTC and few KSRTC buses which moves at grade.
- Proposed Down Ramp towards Sarjapura Road at St. John Hospital junction will allow smooth turning movements in all directions without disturbing the through elevated traffic.
- Continuous vehicle movement without frequent stopping and idling at signals reduces fuel consumption and vehicular emissions.
- Local traffic can use the grade level Hosur Main Road, while through traffic shifts to the elevated corridor, ensuring balanced traffic distribution.
- The proposed alignment is connected to the Tunnel facility by B-SMILE which is being proposed from North to South (i.e, from Hebbal to Koramangala). this facility will be useful for the traffic going up to Bangalore Central, Hebbal and beyond. also connecting National highways NH 44 (Bangalore-Hosur), Banneghatta Road, Outer Ring Road.

CHAPTER- 7 – STRUCTURAL SYSTEM OF FLYOVER

7.1 General

The proposed project is inside the city area. The following points are viewed in selecting structural system for the project –

- The Project under study is very important connection to various parts of the city and complete diversion of traffic is not feasible.
- The construction method and system shall allow the movement of vehicles during construction period with minimum hinderance.
- The construction shall be Precast / prefabricated and segmental to minimise the construction period.
- The precast / prefabricated units shall have high strength to weight ratio.
- Easiness of transportation and erection of precast / prefabricated units.
- Apart from above points it should suit urban architecture with minimum Span to depth ratio

7.2 Drainage System.

Presently Elevated Stretch is having both sides drain and we have not disturbed the flow and alignment of drain. Only proposed new drain where land acquisition / widening of road is necessity.

It is proposed Drainage spouts at interval satisfying the codal guidelines with PVC down take pipe connected to grade level drain to drain out the elevated road rain water.

7.3 Span Arrangement

Span arrangement of 60m and 50.0m is studied and discussed with authority, 50m span is proposed from the following point of view–

1. Depth of Super structure will be more, looks bulky with vertical clearance of 5.5, which will affect the aesthetics.
2. To avoid wider foundation size, which will affect the traffic flow along the corridor.

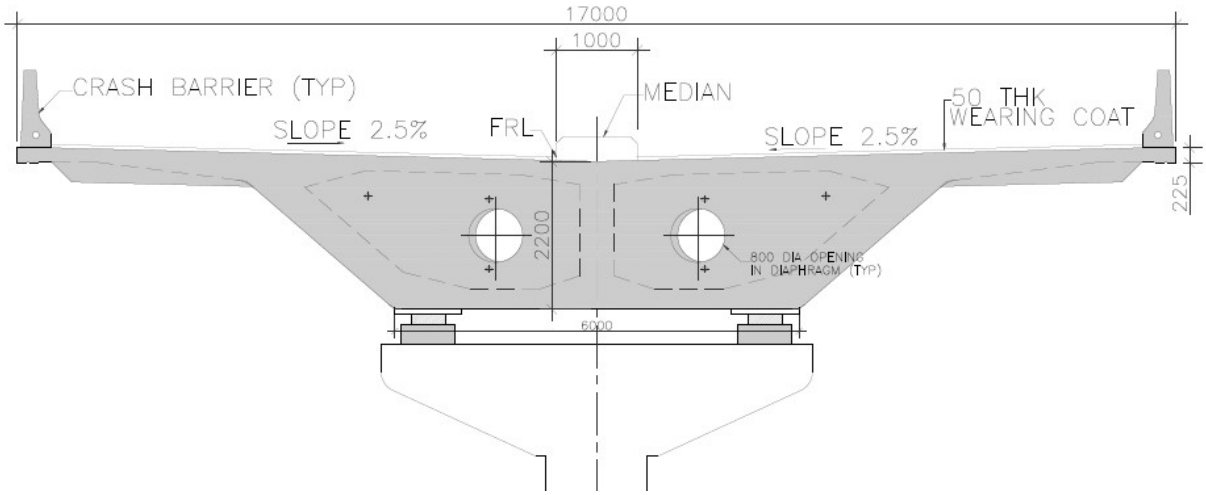
7.3 Options of Super structure.

Following options are studied –

	Span	Structure Type
Option – 1	30	Segmental Box
Option – 2	30	Spine and Wing
Option – 3	45	Composite Steel Girder
Option – 4	50	UHPFRC

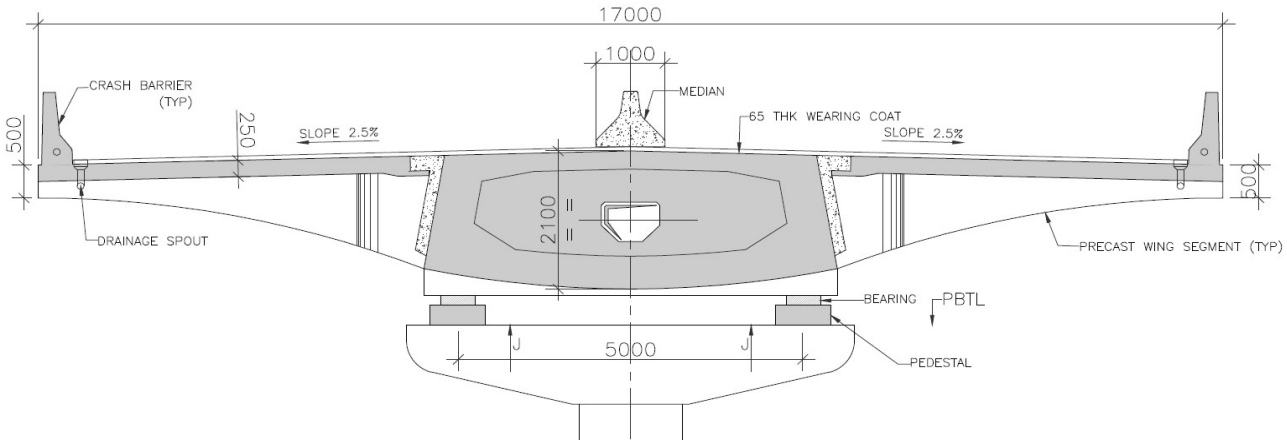
7.3.1 Option – I: Segmental Box Girder

- Construction Speed: The use of precast segments allows for rapid on-site assembly, significantly reducing construction time.
- Traffic Disruption: Minimal on-site activity and a smaller footprint mean less disruption to traffic, making it ideal for urban areas.
- Quality Control: Manufacturing in a controlled factory environment ensures high-quality segments with consistent strength and durability.
- Aesthetics: The slim, clean lines of a segmental box girder can be aesthetically pleasing.
- Cost: The initial investment for casting yards and specialized equipment is high. **The size and weight of the segments will pose challenges for transportation and handling.**



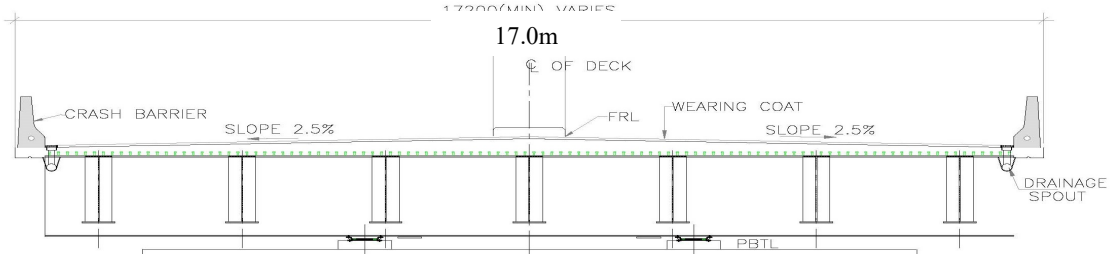
7.3.2 Option – II: Spine and Wing

- Deck Width: The design allows for a very wide deck from a narrow central spine, which is useful for maximizing roadway space.
- Phased Construction: The spine can be constructed first, with the wings added later, which can help with project phasing.
- Aesthetics: The wide, open-deck appearance can be more visually appealing in certain contexts.
- Complexity: The connections between the spine and the wings can be structurally complex and require precise detailing.
- Material Use: **This method often uses a combination of cast-in-situ and precast elements, which can add to the on-site complexity**.



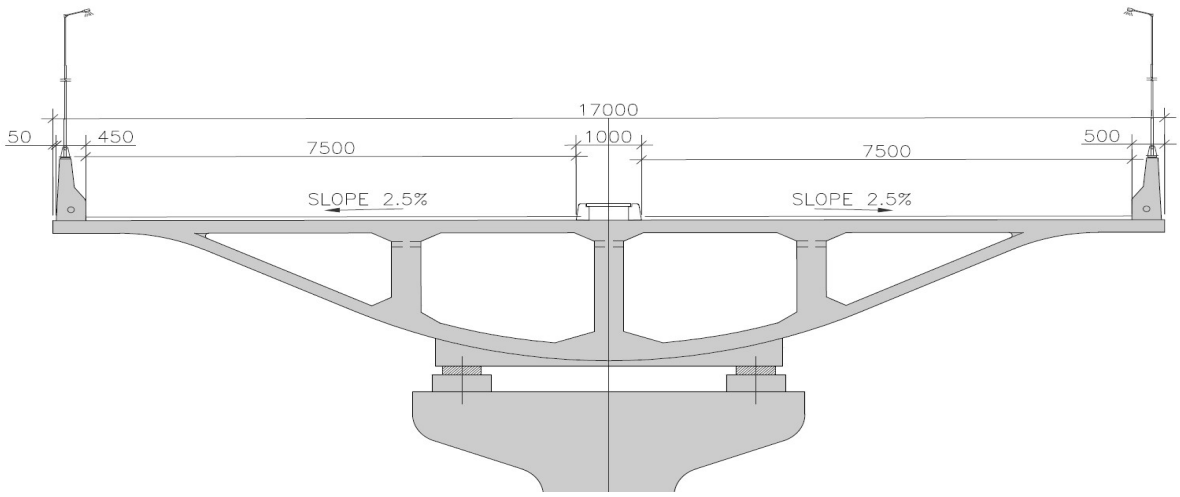
7.3.3 Option – III: Composite Steel Girder

- Weight: Steel is lighter than concrete, which can reduce the size and cost of foundations and supporting piers.
- Long Spans: This is an excellent option for long spans where the self-weight of a concrete structure would be too high.
- Fabrication: Steel girders are fabricated off-site, which allows for faster on-site erection.
- Maintenance: Steel requires regular inspection and maintenance, such as painting, inspection of joints to prevent corrosion, adding to long-term costs.
- Cost: Steel is a more expensive material than concrete, which can increase the initial project cost.



7.3.4 Option – IV: Composite Fish Belly / U-Trough UHPFRC+HPC Slab

- Structural Efficiency: The use of Ultra-High Performance Fiber Reinforced Concrete (UHPFRC) allows for a thinner and lighter structure, reducing dead load on foundations.
- Durability: UHPFRC is extremely dense and resistant to deterioration from chemical attacks, leading to minimal maintenance.
- Construction Speed: The precast U-trough segments can be assembled very quickly, drastically shortening the construction schedule.
- Ease of Transportation: The lightweight nature of the UHPFRC sections makes them easier and more economical to transport from the casting yard to the construction site. This simplifies logistics and reduces costs associated with Transportation.
- Cost-Effectiveness: While the initial cost of UHPFRC may be comparatively higher compared to first 2 options, the reduced material usage, faster construction, and minimal maintenance lead to a lower total life-cycle cost, making it the preferred option.



7.3.5 Superstructure Comparative Study of Cost

Item of Work	Unit	Option -1 (30m Segmental Box)			Option -2 (30m Spin & Wing)		
		Quantity	Rate	Cost	Quantity	Rate	Cost
M50 Concrete	Cum	398.09	14,200.00	5,652,878.00	368	14,200.00	5,225,600.00
UHPFRC -M150	Cum						-
Untensioned Steel	MT	90.2	95,325.00	8,598,315.00	73.83	95,325.00	7,037,844.75
Prestressing Steel	MT	16.5	257,639.00	4,251,043.50	27.6	257,639.00	7,110,836.40
Structural Steel	MT						
				18,502,236.50			19,374,281.15
			Rate/ Sqm	36,278.90		Rate/ Sqm	37,988.79

Item of Work	Unit	Option -3 (45m Structural Steel)			Option -4 (50m UHPFRC)		
		Quantity	Rate	Cost	Quantity	Rate	Cost
M50 Concrete	Cum	194	14,200.00	2,754,800.00	230	7,546.00	1,735,580.00
UHPFRC -M150	Cum				250	97,451.00	24,362,750.00
Untensioned Steel	MT	30	95,325.00	2,859,750.00	55	95,325.00	5,242,875.00
Prestressing Steel	MT				40	257,639.00	10,305,560.00
Structural Steel	MT	310	171,080.00	53,034,800.00			
				58,649,350.00			41,646,765.00
			Rate/ Sqm	76,665.82		Rate/ Sqm	48,996.19

7.3.6 Preferred Option:

Considering minimum inconvenience to grade level traffic during construction, quality of construction, low maintenance requirement, speed of construction, aesthetics**, "Fish Belly and U-Trough UHPFRC" construction (i.e., Option –IV) is the preferred option**

From the Above comparison, comparing direct cost, of construction option 1 and 2 is having least cost. Option-3 is cost prohibitive to adopt for the entire corridor. Option-4 with 50m UHPFRC composite super structure the cost of super structure is about 28% higher compared to option-2. However, there will be reduction in cost of sub structure Super structure with UHPFRC composite i.e., **Fish belly & U- trough with UHPFRC and top slab with M50 is recommended with following advantages.**

1**. Sleek sections and elegant appearance of structure.**

2. Significant reduction in the weight and hence suitable for long spans.

3. Ensures high quality of concrete as it is produced with less w/c ratio in a controlled environment.

4. Attains early strength and hence faster construction cycle which reduces construction period.

5. Life cycle cost is less as the maintenance requirement for UHPFRC is negligible

6. Significant reduction of Shrinkage and creep.

Though cost of construction for Composite steel super structure is more, composite structural steel super structure is proposed for elevated rotaries, rotary adjacent spans, at few critical locations keeping ease of construction point of view.

7.3.7 Sub structure and Foundation

Sub structure is proposed with RCC single rectangular piers for main corridor and approaches.

For piles Bored cast in situ Piles of 1350mm dia is adopted for main carriageway and 1200mm dia pile for standalone flyover and down ramp structure. Open foundation is proposed BMRCL Metro Tunnel above piers.

7.3.8 Bearings & Expansion joints

Mechanical Bearings, spherical bearings are considered and Slab seal expansion joints are used.

CHAPTER- 8 – TRAFFIC DIVERSION AND MANAGEMENT PLAN

8.1 General.

The existing 4 lane Road over which Elevated Corridor is proposed is a vital connection to many important locations of the city.

The major roads around this corridor are, Brigade Road, MG road, Sarajapura Road, Madiwala Junction, Bannerghatta Road, Hosur Road, Koramangala 21st Main, in view of heavy traffic on the major roads around the Junction and connectively of North Bangalore towards Bellary Road and Old Madras roads traffic diversion from junction under study is not feasible, hence only “Traffic Management” is to be planned, allowing the vehicle movement along the corridor.

To minimise the least hindrances to the traffic movement following measures has been taken while preparing the proposals –

- Precast technology is adopted which will be erected using Overhead launching girders/underslung system.
- Existing service roads will be resurfaced and new service roads for construction purpose will be formed
- Constructing the new service roads wherever there is no existing service roads
- Barricading the construction site
- Deployment of Flagmen
- Proper signage’s at the working area indicating diversions and other cautionary sign boards.

Traffic management to be followed along existing road.

Traffic management may be under following guidelines during various phases –

8.2 Traffic Management during Construction.

8.2.1 Phase – I: Widening and resurface of existing slip/service road is planned during this phase.

Hard barricading and safety measures are proposed in the construction area, allowing the traffic movement along the existing carriage way –

8.2.2 Phase – II: Construction of Viaduct is planned during this phase.

Hard barricading and safety measures are proposed in the construction area, allowing the traffic movement on either side over existing and extended carriage way.

8.2.3 Phase – IV: Reconstruction of grade level roads is planned during this Phase.

The through traffic is allowed over the viaduct. The reconstruction of service road shall be taken up one after the other, to facilitate traffic movement towards cross roads.

The above scheme of traffic management is tentative which is to be approved by the traffic police and the responsibility of approval and implementation rests with construction agency.

CHAPTER- 9 – LEGAL ASSESSMENT

9.1. Land Acquisition

The Project Area lies in Well Developed Residential as well as in Commercial Area 2405 Sqm of private land needs to be acquired under Transfer of Development Rights (TDR) Scheme for the proposed Elevated Road from Madiwala to Shooley Junction. Details of Land Acquisition are given in Drawing No: NC/ B-SMILE/ADUGODI/LA-01 (Sheet 1 of 3 to 3 of 3).

9.2. Enforcement Measures

B-SMILE has planned to take Precautionary Measures during the Construction Phase to enforce Traffic Diversion and minimizing the effects of various Pollutions. Through the Institutional Framework suggested, B-SMILE will coordinate with the Traffic Police, BMTC and Utility Operators like BESCOM, BWSSB for the Shifting of Existing Utility Lines, which are going to obstruct the Execution of the Project. Since BSMILE is the Obligatory Provider of Citizen Services in the City, it has powers by statue to require other Government and Non-Government Agencies to implement Plans in Public Interest. B-SMILE has also notified the List of Underpasses and Flyovers that it proposes to construct and thus it is making the Residents and Commercial Establishments aware of the possible disturbances that could emerge on account of the Implementation of the Projects.

Present Proposal crosses the proposed phase 3 metro line at Anepalya Junction and beyond and going towards Shooley junction along Hosur Road. We understand the BMRCL facility is underground, and it will be at around 14m below ground level. It may be with twin cell tunnel with overall 15m width including 2m clearance between 2 cells. Our arrangement is fall on the metro line, further discussion with BMRCL it is proposed open foundation for piers above metro tunnel.

Other stake holders along the corridor whose utilities are crossing the present proposal viz., KPTCL, BESCOM, BSNL , etc., are informed regarding the project with a letter and set of project drawings and costing towards necessary utility shifting are accounted in the DPR.

CHAPTER- 10 – RISK ASSESSMENT

10.1. General

In a Road Project there are considerable risks involved during the implementation of the project. The risks during the operation phase are minimal and restricted to over use of the road (against Design Assumptions) by heavier vehicles and damage to road surface by accidents and by vehicles carrying overload. In the current elevated road projects undertaken by B-SMILE, the time frame for completion varies between 18 to 24 months after mobilization of site resources. The major risk relates to buy in of the project from all stakeholders, especially those affected by the construction itself. These are residential and commercial establishments who are close to the construction site. They are exposed to noise pollution, dust pollution and inconvenience caused due to inability to use their vehicles on account of temporary closure of the roads.

Internal Risks come mainly from three sources: the Project, the Organizations Involved and the Relationships among Partners. Most projects suffer at least temporarily from a deficient project structure: many are launched even though objectives are not clear, a business case had not been completed, and milestones were only vaguely defined, if defined at all. These instances of lack of or inadequacy in definition of scope occur due to pressure to complete the planning stage and to go ahead with the construction early. On the organizational side, lack of project control mechanisms is the factor that most impede many projects. Finally, risks associated with the relationships among partners have been the major source of concern present in all projects, lack of definition of role and responsibility as the most important problem for project implementation.

The Risks associated with the road projects fall into four categories.

- Multiple Stakeholder Coordination Risk during execution of work (very critical in the road projects of Bangalore).
- Project Risk (Clarity in Scope, Clarity in Role and Responsibility).

- Acquisition of Land and Removal of Encroachments while Widening the Drains.
- Shifting of Utilities – Perfect Coordination among the Concerned Stakeholders and the Contractors.

10.2. Stakeholders

The Stakeholders involved in the Bangalore Road Projects are:

- B-SMILE.
- Utility Companies.
- Traffic Police.
- Public Works Department.
- Residents' Association.
- Shop Owners' Association.
- Pollution Control Board.

10.3. Role of Traffic Police

Coordination with the Traffic Police, Liaison with Residents and Shop Owners' Association is a pre requisite before commencing the Construction Phase. Traffic Police will have to plan for Diversions/management of traffic, Construction of Temporary Structures, and Regulation of Traffic during Peak Hours with Extra Resources, etc. Communication through Media and Door – to – Door Campaign in the affected areas are proposed to ensure smooth Construction Phase.

Traffic Police will also have to develop alternate routing for the BMTC Buses that ply in the roads proposed for revamping. They need to mark the zones near the Construction Site as 'No Parking' and allocate Routes and Space for the Vehicles engaged in the Construction Work.

10.4. Shifting of Utilities

In Bangalore Road Network, the common Utilities that are encountered during the revamping or widening are

- Sewer and Drainage Lines.
- Water Supply Lines.
- Electricity Lines and Structures (Mounted Transformers).
- Telecommunication Lines and Structures.
- Street Lights.
- Parking Signs.
- Post Boxes.
- Signals.

The utilities are to be shifted in coordination with the Concerned Departments. The key is in sending them advance communication and obtaining their sign off for proposed shifting well ahead of the Construction Phase. Underground utilities are the main concern and pose a major challenge that will need the commitment and cooperation of all the associated Departments. Shifting of underground utilities are to be executed in coordination with BWSSB, KPTCL, BESCOM, BSNL and other private Telecom Operators like Bharti, Tata, Reliance, etc., which have led OFC cables along the existing roads.

10.5 Risk Management

Risk	Stakeholders	Severity of Risk	Solution
Acquisition of Land	B-SMILE, Government of Karnataka	Medium	A Combination of Enforcement and Rehabilitation measures is required to notify the affected people and provide Alternate Arrangements for living. In the case of road projects the instances are minimal.
Removal of Encroachments	B-SMILE, BDA, Government of Karnataka	Medium	Legislation followed by proper Enforcement; affected people to be considered for Housing under Basic Services to Urban Poor Plan.
Traffic Management	B-SMILE, Contractors, Traffic Police	High	A Well-Coordinated Traffic Management Plan with clearly Defined Roles is required. Participation of Residents and Shop Owners at the Formulation Stage is also recommended.
Risk	**Stakeholders**	**Severity of Risk**	**Solution**
Accident Free	B-SMILE, Contractors, Traffic Police	Medium	Proper Deployment of Resource at critical periods of time and Inspection of Vulnerable Structures and Traffic Diversion Routes.
Dumping of Construction Debris	B-SMILE, Contractors	Medium	Storage Space shall be allocated along the Construction Site, Instructions for Clearing and Dumping the Debris Outside the Construction Sites shall be issued.
Protection of Pipe line	B- SMILE, BWSSB and Contractors	Medium	The water pipe line of larger diameter along the pipe line corridor shall be protected by MS encasement at pile and pile cap location
Compound wall	B-SMILE, Contractors	Low	Wherever construction is in close proximity to the structure and in forest area compound wall to be constructed

10.6 Internal Risks associated with Road Projects in Bangalore City with Suggested Measures to Address the Risks

Risks Associated with the Project itself	***Characteristics of Clients / Users of the Service:*** Resistance to Change, Lack of Involvement, Inadequate Education Level, Difficulties in Communicating, Unrealistic Expectations. (To overcome B-SMILE is seeking Citizen Participation through Ward Committees and others for Buy In the Project and Speedy Implementation). ***Scope of the Project:*** Universality or Specificity of the Service, Number of Partners Involved, Number of Clients, Size of Budget. (Contract Documentation being revamped to define the Role and Responsibility very clearly emphasizing on the need to communicate with the Stakeholders at the Critical Times). ***Complexity of the Project:*** Especially Organizational and Technological Complexity. (Consultant would evaluate various assumptions made in the Design and Detailed Engineering while executing the Project and provide Feedback to B-SMILE). ***Definition and Structure of the Project:*** Unclear Objectives, Ill Defined Specifications and Functional Requirements, Changes in the Scope or the Reach of the Project, Difficulties in Integrating Data or Processes. (Flexibility to Accommodate Changes by the Contractors included in the Contract Documentation).
Organizational Risks	***Lack of Resources:*** *U*ncertainty of Funding, Inadequate Resources, Lack of Expertise in Complex Resource Management (these may not be critical under State Govt Funding). ***Project Team Competencies:*** Lack of Experience, Expertise, Stability and Communication Skills. (It is proposed to establish a PMU for Road Projects within B-SMILE with Requisite Skills and Experience). ***Management Strategy:*** Inadequate or Inappropriate Organizational Support and Control, Absence of a Champion, Lack of Leadership, Unavailability of Tested Management Tools and Processes. (Inter Institutional Committee proposed to deal with Policy Level Decisions including Release of Funds from the State Government). ***Technological Know How:*** Absence of an Adequate Technological Infrastructure and of In-House Technological Competencies. (Competencies being Upgraded as well as Latest Construction Practices followed in Road Construction, Material Handling and Disposal of Construction Debris).
Relationship Risks	***Form of Collaboration:*** Inadequate or Inappropriate type of Agreement, Misunderstandings regarding the Content of the Agreement, Inappropriate Selection of Partners, etc. (All Contractual Frameworks to define the Role, Responsibility and Liability of Various Parties clearly; Contractors to be provided with Opportunity to seek Clarification before Accepting the

	Work). ***Collaborative Process:*** Problems occurring with Coordination, Communications, Inertia, Dependency, Mistrust, Lack of Consensus or Involvement (Change Management Process proposed to be handled by the PMU).

CHAPTER- 11 – ENVIRONMENTAL AND SOCIAL IMPACTS

11.1. General

In any major developmental initiative aimed at promoting the interests of the community or the State / Country, the Associated Environmental Impacts – whether of a Short Term or Long-Term Nature, likely to affect the Environment, Ecology and Health of the Community, need to be seriously examined, before embarking on the proposed project. The Primary Objectives of the Environmental Impact Assessment (EIA) are to evaluate the existing pre operational baseline environmental status at the proposed project site by field studies and data collection, and then carry out an Objective Assessment of the various impacts on the Environment as a result of the proposed activities.

As "Construction of Elevated Corridors from shooley Circle to st.John Hospital Road on Hosur Road via Anepalya Junction and Adugodi Junction in Bengaluru " is one of the major Metropolitan Infrastructure Projects for Bangalore, it is imperative to conduct an Environmental Impact Assessment (EIA) to quantify the Benefits accrued to the Community as a result of the Project, while at the same time analyzing carefully the Impact Aspects due to the Project itself, during Construction and Operation Phase Cycles. As these Data are crucial for the Planning and Successful Implementation of the Project, Various Data (such as Nos. of Tree Cutting, Extent of Air and Noise Pollution, etc.) have been collected from extensive site studies in accordance with well-established Standard Procedures.

The existing road infrastructure on Hosur Road have deteriorated remarkably as a result of lack of investment and multifield increase in traffic volume and have to be upgraded to higher service levels in order to reduce transport cost in support of Socio-Economic Development.

Discussions held with Government and Non-Governmental Organizations and a Detailed Site Assessment have been carried out to provide the basic background for Impact

Identification and Assessment. A Scoping Exercise has also been carried out at the Pre-Construction Stage to identify and highlight the Key Issues and Impacts likely to occur during the Construction, Operations and Maintenance Phases of the Project, as well as to identify those Impacts which could, but are unlikely to occur. Practical and Cost-Effective Benefit Enhancement and Mitigation Measures have been identified and outlined, taking into account alternative approaches that are appropriate to the situation. A Management and Monitoring Plan was developed to provide a sound basis for ensuring that the specified benefit enhancement and mitigation measures are fully adopted.

For Planning and Implementation of “Elevated Corridor”, we have given due attention to the Environmental and Social Issues. The Various Issues addressed under this Section are as follows.

11.2. Environmental Impact

11.2.1. Green Cover

Bangalore City – with its rich flora and abundant green cover and being host to Lalbagh and Cubbon Park, which are renowned botanical gardens, is rightly called the "Garden City of India". Bangalore City bagged the Central Government sponsored "Indira Priyadarshini Vruksha Mitra" Award in the late 1980s in recognition of its extensive green cover. But today, lung space is shrinking in the city and core areas have lost green cover with increase in concrete structures. As a part of this project, to acquire obstruction free area, 60 trees to be cut in the project area. Considering the Benefits of the Project and the Compensatory Afforestation Plan envisaged, it has been observed with management plans consisting of planting of trees in the ratio of 1:2, proactive afforestation for green cover and development of green ribbon in and around the project area, it will be abundantly compensating the green cover. for number of trees to be chopped, afforestation and translocation of trees have been planned.

11.1.2 Air Pollution

Air Pollution level will go up during the Construction Stage due to operation of construction yards, material transport on trucks and due to heavy earth moving machinery exhaust emissions (e. g. SPM, RSPM, NO_x, SO_x, CO, etc.) from the construction sites. These are not permanent in nature, but minor, temporary and mitigatable. In the post construction scenario, the General Level of Air Pollution in the project area will be significantly less than the current level due to improved movement of vehicular traffic and removal of idling time and thus this project ensures better environment. The Consultant has collected data regarding existing Air Quality in and around the project area and is studied. All vehicles delivering materials to the site will be covered to avoid spillage of materials. All existing highways / roads used by vehicles of the Contractor, or any Sub Contractor or Suppliers of Materials or Plant and similarly Roads, which are part of the Works, will be kept clean and clear of all dust / mud or other extraneous materials dropped by such vehicles. The unloading of materials at construction sites close to settlements will be restricted to night time only. Vehicles and

Equipment will be fitted with Exhaust Silencers. During routine service operations, the Effectiveness of Exhaust Silencers will be checked and if found defective will be replaced. Unpaved Haul Roads near / passing through residential and commercial areas to be watered thrice a day. Trucks carrying construction material are to be adequately covered. All Earthworks will be protected in a manner acceptable to the Engineer (such as Barricading the Construction Site) to minimize Dust Nuisance in the surrounding area. The Contractor will take every precaution to reduce the Level of Dust along Construction Sites involving Earthworks, by frequent application of water.

11.1.3 Water and Soil pollution

The Surface and Underground Water and Soil Pollution Aspects are not likely to be greatly influenced, unlike Air Pollution Quality by the Construction of Elevated Corridor along Hosur Road from shooley Circle to st.John Hospital, However, there could be Indirect Impact on the Water and Soil Components in the long run.

As the Project Activities need substantial water quantities for construction processing, dust proofing, cleaning of vehicles and batch mixing, etc. there could be considerable demands on water resources available. Necessary arrangements and contingency plans with BWSSB and Arrangement for Supply of Recycled Water should be made to meet the Water Demands, without in anyway affecting the city's normal water supply demands.
With the proposal of UHPFRC (Ultra High Performance Fibre reinforced concrete), HPC (High Performance Concrete) and Composite steel girders, water requirement is minimised. With the proposal of Pre cast UHPFRC, where curing will be with steam curing, recycling of the water can be made there by reduction in the water requirement.

All the Proposed Project Components will be in Well Developed Areas of the City with Distinct Land Usage Patterns ranging from Residential to Commercial Activities under Well Established Conditions. As Construction Activities are primarily land based, many Impacts can be identified in the Soil Component in the Proposed Area. Excavation Activity will produce a lot of rubble from excavated soil, needing disposal. The excavated

soil / debris will be disposed by covered trucks to avoid Dust Nuisance in the Project and Surrounding Areas. Debris generated due to the dismantling of the existing pavement structure shall be suitably reused in the Proposed Construction, subject to the Availability of the Material and the Approval of Project Engineer. The Contractor shall suitably dispose of Unutilized Debris Material; either through filling up of Borrows Areas created for the Project or at Pre-Designated Dump Locations, subject to the Approval of the Project Engineer. Debris generated from different Construction Activities shall be disposed of in such a way that it does not flow into the Surface Water Bodies or form Mud Puddles in the area.

As the concrete used for sub structure is from RMC, water required only for curing purpose only. For Curing purpose, potable water shall be used and percolating water will not pollute the ground water table.

11.1.4 Noise Pollution

As the Project involves significant uses of Heavy Machineries, Traffic Diversion, etc. hence Noise Concern will be a major issue during Construction Phase. But the Post Construction Scenario ensures a Better Environment in the Project Area, as the General Level of Noise Pollution in the Project Area will be significantly less than the Current Level due to Improvement in the Movement in Vehicular Traffic and Removal of Idling Time. The Consultant has collected existing Noise Level Data in and around the Project Area and studied. To mitigate the Noise Impact, Direct Technical Remedies including Low Noise Road Surface, Road Covers and Roadside Noise Barriers will be provided. Noise Limits for Construction Equipment used in this Project (measured at one metre from the edge of the equipment in free field) such as Compactors, Rollers, Front Loaders, Concrete Mixers, Cranes (movable), Vibrators and Saws will not exceed 75 dB (A), as specified in the Environment (Protection) Rules, 1986. Notwithstanding any other Conditions of Contract, Noise Level from any Item of Plant (s) must comply with the Relevant Legislation for Levels of Noise Emission. The Contractor will ensure that the AAQ Concentrations as these Construction Sites are within the Acceptable Limits of Industrial Uses in case of Hot Mix Plants and Crushers and Residential Uses around Construction Camps. Noisy Construction Operations in Residential and Sensitive Areas

(Hospitals, Schools and Religious Places) should be restricted between 0730 hrs. and 1800 hrs. Preventive Maintenance of Construction Equipment and Vehicles would be done to meet Emission Standards and to keep them with Low Noise. Earplugs will be provided to Operators of Heavy Machinery and Workers in near vicinity. Material Transport should be uniformly distributed during nights to minimize Noise Impacts. Noise barriers will be proposed at required locations in discussion with clients. Mainly near the Schools, Residential developments, Hospitals and Temples.

Part of the Costs, particularly the Implementation of Environmental Measures is included in the Unit Rates for the Works and is responsibility of the Contractor.

11.1.5 Social Impact

The Direct and Indirect Job Opportunities that will be provided by the Project can be considered as a Positive Aspect. The Local People will be directly employed to work at the Construction Sites and others will be employed in Sectors of the Economy, which have been developed by the Road such as the Service Sectors. Some individuals may gain skills that can be applied in other Road Construction Projects.

Contract Documentation will be crafted in such a way that the Construction Work does not cause undue Inconvenience to Residents, especially the Sick and Old People. Removal of Construction Debris promptly from the Site falls within the Scope of Work of the Contractor. Asphalting, the Major Work, involved in the Road Construction would invariably be carried out during the nights with Proper Inspection Team supervising the Process.

The table below summarizes the Negative Environmental and Social Impacts and Mitigation / Benefit Enhancement Measures for the Negative Impacts, as well as the responsible body to implement the measures.

Type of Impact	**Mitigation Measure**	**Responsible Body for Implementation**
Impact on Settlement	Minimize the Risk at the Road particularly in a Dense Settlement Area.	Consultant and Contractor.
	Allow Affected Persons to Salvage Building Materials and other Assets.	B-SMILE and Contractor.

	Pay Compensation and Resettle the Affected People.	B-SMILE.
Impact on Health	Do not Induce Water Related Diseases by creating Temporary and Permanent Water Holding Areas, which favour Mosquitoes.	B-SMILE and Contractor.
	Minimize Dust Emission by Watering the Road during Construction.	Contractor.
	Put Visible and Appropriate Warning Signs on the Road during Construction.	Contractor.
Impact on Existing Infrastructure	Relocate Power Lines, Telephone Lines and Water Points before Commencing of the Road Construction and in few cases during the Construction Phase.	Utility Companies and Contractor.
Impact on Cultural, Religious and Archaeological Resources	Design Roads to avoid such Sensitive Places.	Design Consultant.
Road Safety during Construction and Operation Phase	Install Road Safety Signs at all Accident Prone Spots as Installation / Erection of Safety Signs.	Traffic Police / Contractor.
	Provide Traffic Awareness.	Contractor in collaboration with Traffic Police of the Area and Local NGO.
	Use Clear, Properly Labelled and Meaningful Traffic Signs and Speed Limits, especially at Pedestrian Road Crossing.	Contractor in collaboration with Traffic Police of the Area.
	Assign Traffic Personnel to regulate the Passage of Construction Vehicles (carrying debris as well).	Contractor in collaboration with Traffic Police of the Area.
	Construct Half of the Road while the other is used for Traffic where feasible.	B-SMILE and Contractor.
Social Impact from Migrant Workers	Construction Workers will be given Health Awareness.	NGOs in collaboration with the Contractor.
	Avoid accommodating Labour Force in or directly adjacent to Construction Sites.	Contractor.
	Recruit Work Force from the Local Community giving more chances to Women.	B-SMILE and Contractor.

11.1.6 Requirements for Prior Environmental Clearance:

As per EIA notification 2006, a prior environmental clearance is required for highway projects as mentioned in cl 2 and schedule to the clause 2. The extract of the same is presented below-

2.0 Requirement of prior Environmental clearance (EC): Following projects/Activities shall require prior environmental clearance from concerned regulatory authority, which shall hereinafter referred to be as the central government in the ministry of Environmental and forests falling under category "A'" in the schedule and state level, The state Environmental Impact assessment Authority (SEIAA) for matters falling under category "B" in the said schedule.

Schedule : List of Projects OR Activities requiring Prior Environmental clearance

Project/Activity	**Category with Threshold Limit**		**Condition if any**
	A	**B**	
7(f) (Highways)	i. New National Highways and ii. Expansion of National highways greater than 30km involving additional right of way greater than 20m involving land acquisition and passing through more than one state	i. New State Highways and ii. Expansion of National highways/State highways greater than 30km involving additional right of way greater than 20m involving land acquisition.	General Condition shall apply

Since the project under this Detailed Project report doesn't fall under the category of A or B as per the notification/schedule the project does not require Prior Environmental clearance as per the notification.

CHAPTER- 12 –PARTICIPATION OF BENEFICIARIES

- Any Infrastructure Development Activities of B-SMILE are planned and implemented through Community Participation Process. Local Government Institutions at various levels are involved in the Implementation of Projects. Moreover, NGOs are involved to assist B-SMILE in Social Mobilization Aspects for Planning and Implementation of the Project. As a part of Participatory Development, Beneficiary Groups and User Committees, such as Labour Contracting Society, Market Management Committee, Road User's Committee, Water Management Committee, etc. have been consulted under various Projects of B-SMILE. Involvements of the Private Sector, Local Government Institutions, NGO and Beneficiary Groups have significantly contributed to Smooth Planning, Implementation and Operation / Maintenance of Infrastructure Development Schemes of B-SMILE at the Local Level. Consultation with various Stakeholders has been an Integral Part of Project Formulation Phase. People have been interviewed along the route, including Elders and Elected Members of the Community; have given a positive reaction to Road Improvement. The Project Junction is very important in terms of connecting the National Highways. Social Acceptability of the Project Junction is very high.

- This Project will have many Positive Impacts on Beneficiary Livelihoods and in the Potential Economic Expansion of the Region. Beneficiaries of this Project include Bangalore Metropolitan Transport Corporation (BMTC) Authority, Commuters using this stretch of road, Local People in and around of the Project Area.

- Public Opinion with regard to public projects cannot be ignored. It plays a very important role in the decision-making process. Given the chaotic road traffic on JC Road, Public Opinion Survey is conducted on the basis of a sample of cross section of intelligentsia drawn from Lawyers, Doctors, Engineers, Academicians, Journalists, etc. the Opinion Makers in Urban Situation upon finalisation of GAD after the approval TAC and B-SMILE. Interactive Sessions with NGOs and Various Members of the City Public also formed part of the Exercise in this Direction.

- Prior Information to the Public, before the Start of the Work, regarding the Project will be given through Paper Notification.

- Boards, comprising Important Data regarding the Project (such as Project Name, Name of the Agency executing the Work, Name of Local Government Body taken up the Project, Date of Commencement of the Project, Projected Date to Complete the Work, etc.) for notifying people will be displayed at the major junctions in and around the project area.

- Adequate actions to direct and regulate traffic shall be taken in consultation with B-SMILE / Traffic Police to prevent jamming roads during Construction Period. While planning alternative routes, care to be taken to minimize congestion and negative impacts at sensitive receptors such as Schools and Hospitals. Traffic Controls and Diversions marked with Signs and Lights and Other Measures (flags) should be provided. Prior to creating Diversions and Detours, the citizens will be consulted well in advance through Citizen's Meetings. It should be an informed decision taken through Public Participation. The Temporary Traffic Detour will be cleaned regularly.

- Another significant aspect of the Construction of Elevated Corridor from shooley Circle to st.John Hospital Road on Hosur Road, would be its Dislocation Effect on the existing public utilities like Electrical System Network (including Street Lighting), Sewerage Lines and Water Supply Network, etc. As the Public Utility Network are very vital for a normal functioning of an Urban Metropolis, a Detailed Survey of Existing Utilities and their Diversion or Reinstallation on a temporary or permanent basis should be planned in a proactive manner and organized with minimum loss of time and inconvenience to the community. Prior Information through Paper Notification will be given to the affected area people before shifting any Utilities.

- The Project is judged to be environmentally and socially acceptable.

CHAPTER- 13 – CONCLUSIONS AND RECOMMENDATION.

13.1 CONCLUSIONS

The Project is highly beneficial to the road users and public. Therefore, the construction of Proposed Elevated Corridor from shooley Circle to st.John Hospital Road on Hosur Road" coupled with the traffic management will have the following additional benefits:

- Reduced junction delays and pollution due to vehicular traffic.
- Reduction in idle fuel consumption
- Improved level of service at the Junctions along the existing corridor
- Substantial savings in travel time for Road users
- Reduces the number of conflicts for through traffic.

PROPOSAL

- 4 Lane bi directional elevated corridor from Madiwal junction to Anepalya Junction along Hosur Road.
- 3 lane in both direction standalone flyover at Shooley junction for eliminate complicit at Shooley junction for Hosur main road traffic.
- down ramps in front of St. John Hospital along Sarjapura Road is proposed for Koramangala traffic movement.

13.2 Recommendations and Conclusion

- Presently through traffic is moving along the congested Hosur Road, passing through 6 junctions with a traveling time of 40 to 50 min.
- Traffic along the corridor is heavy at present junction peak hour traffic volumes are crossed/nearly crossing 10000 pCU
- LOS along the corridor varies from D to F during the pek hours. By adding 4 lanes at elevated road and streamlining at grade roads to 2 x 7.5m (minimum) along the corridor smooth traffic flow on atgrade level road is ensured.

- With the construction of elevated corridor along Hosur road, through traffic will be unhindered and traveling time will reduce to less than 15min
- There will be reduction in Vehicle operating cost
- There will be reduction in pollution level, especially at junctions, where waiting time will be reduced due to elimination of conflicts at grade level vehicles
- Apart from through traffic, with the provision of exit ramps at Sarjapura Road the connectivity will be improved for the population of Koramangala, HSR layout.
- The proposed alignment is connected to the Tunnel facility by B-SMILE which is being proposed from North to South (i.e, from Hebbal to Koramangala). this facility will be useful for the traffic going up to Bangalore Central, Hebbal and beyond. also connecting National highways NH 44 (Bangalore-Hosur), Banneghatta Road, Outer Ring Road.
- Separate Fly over at Shooley junction, accommodating through traffic along Hosur Road, will decongest the junctions and reduces the signal timing and waiting time at the junctions.
- Noise level and pollution level along the Hosur road will be reduced as the through traffic is taken along elevated corridor.

APPENDIX - 1 - TRAFFIC REPORT

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1. CHAPTER 1: TRAFFIC SURVEYS AND ANALYSIS

1.1 INTRODUCTION

The **Bengaluru Smart Infrastructure Limited (B-SMILE),** a Special Purpose Vehicle (SPV) dedicated to executing large-scale urban development projects awarded the project "Consultancy Services for preparation of Detailed Project Report for the work of " **Construction of Elevated Corridors from sholay Circle to st.John Hospital Road on Hosur Road via Anepalya Junction and Adugodi Junction in Bengaluru Central and South City Corporation limits** to **M/s. NAGESH Consultants, Bangalore** to carry out all engineering surveys. This report presents the traffic studies and analysis along the corridor.

The traffic survey was conducted to study the existing movement of traffic and to calculate the diverted traffic movement from existing roads to proposed elevated corridor and the traffic survey data are presented in terms of Average Daily Traffic (ADT) along the project road. These results of the analysis can be used or will form inputs for traffic forecast, determination of capacity analysis and design of other project proposals.

1.2 The Traffic Survey Location

The schematic diagram of traffic survey locations is given in **Figure 1.1**. Traffic surveys are conducted at selected locations along Hosur Road. The list of surveys conducted is given in **Table 1.1** below.

Figure 1.1 Traffic Survey Location Plan

1.3 TRAFFIC SURVEY LOCATIONS

The following survey locations were selected for the traffic surveys and the schedule of traffic surveys is presented below. The following **Table 1.1** gives details of various traffic surveys conducted with period of survey.

Table 1.1 Schedule of Traffic Surveys

Sl. No.	Type of Survey	Duration	Location	Date(s) of Survey
1	Turning Movement Surveys	24 Hrs	Shooley Junction	18.10.2025
2		24 Hrs	Adugodi Junction	
3		24 Hrs	St John's Hospital Junction	
1	Origin-Destination Survey	Peak Hours	Adugodi Junction	
3		Peak Hours	St John's Hospital Junction	

1.4 SURVEY METHODOLOGY AND CONDUCT OF SURVEYS

The Origin and Destination survey was carried out manually by employing enough specially trained enumerators. An experienced traffic engineer was kept in charge while carrying out the surveys. The locations for the various surveys were selected based on the discussion with NAGESH Consultants and members from Jayanth Seelin Associates:

1.5 CLASSIFIED TRAFFIC VOLUME COUNT

The classified traffic volume count was carried using Videography method. Cameras were installed at the survey locations covering all traffic movements. The traffic data captured in the camera are downloaded to the computer after completing the survey. The captured data was counted manually at the office to obtain data on the magnitude of traffic flow, hourly variation and the traffic composition. The vehicles were broadly classified into various categories such as cars/jeeps/vans, buses, trucks, multi axle vehicles (MAVs), light commercial vehicles (LCVs), tractors, motorized two wheelers, auto rickshaws and slow-moving vehicles (SMVs) which includes cycles and carts.

1.5.1 Passenger Car Unit

A way of accounting for the interaction of various kinds of vehicles is to express the capacity of roads in terms of a common unit. Tentative equivalency factors for conversion of different types of vehicles into equivalent Passenger Car Units (PCU) based on their relative interference value. Table **1.2** presents the PCU factors (As per IRC: 106-1990) considered in the estimation of traffic intensity in PCUs.

Table 1.2 PCU factors adopted

Sl. No	Vehicle Category	PCU Factors
1	2-Wheeler	0.75
2	3-Wheeler	1.2
3	Car/Jeep/Van	1.0
4	Mini-Bus	1.4
5	Bus	2.2
6	LCV	1.4
7	2 Axle Truck	2.2

Sl. No	Vehicle Category	PCU Factors
8	3 Axle Truck	2.2
9	4-6 Axle Truck	4.0
10	Tractor with Trailer	4.0
11	Tractor without Trailer	1.4
12	Cycle	0.4
13	Cycle Rickshaw	1.5
14	Animal Drawn	1.5
15	Animal Drawn	1.5
16	Others HCM/ EME	2.2

1.6 TURNING MOVEMENT COUNT SURVEYS

The surveys were conducted for one day (24 Hours covering morning and evening peak hours) to obtain classified turning movement at the identified junctions. The data derived from the survey will be analyzed to identify requirements of suitable remedial measures, such as construction of grade-separated intersections.

1.6.1 TMC 01 (Shooley Junction)

- A total of about 1,39,350 vehicles (1,32,552 PCU's) pass at this location per 24 Hours.
- Goods vehicles account for 3.91% and passenger vehicles account for 95.84% of the total traffic. Non-motorized traffic constitutes about 0.24% of total vehicles.
- Among the passenger vehicles, two wheelers and cars are the dominant ones constituting about 53.17% and 27.84%. Whereas Auto Rickshaw and buses (Minibus, Pvt. Bus, Govt. Bus) are at 14.83%.
- Morning Peak Hour at 09.00 AM to 10.00 AM (7.27%, Peak Hour Factor) and Evening Peak Hour at 19.00 PM to 20.00 PM (5.97%, Peak Hour Factor).

  Figure 1.2 and **Figure 1.3** shows Traffic Composition and hourly variation of traffic at location. Direction-wise Flow diagram is given in **Figure 1.4** to **Figure 1.5.**

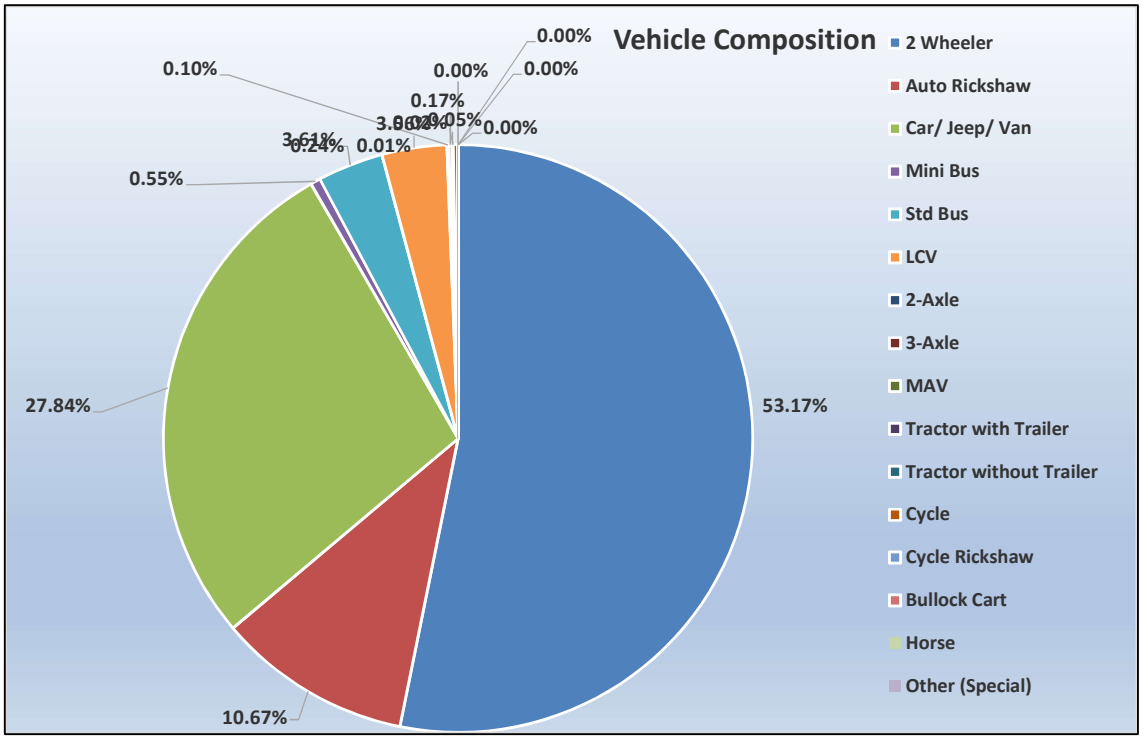

Figure 1.2 Traffic Composition at Shooley Junction

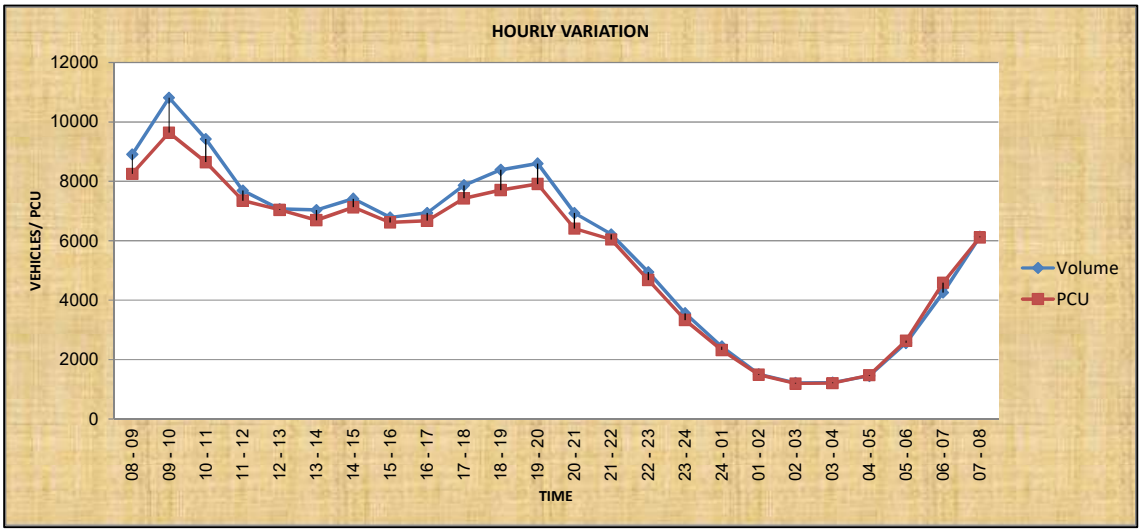

Figure 1.3 Hourly Traffic at Shooley Junction

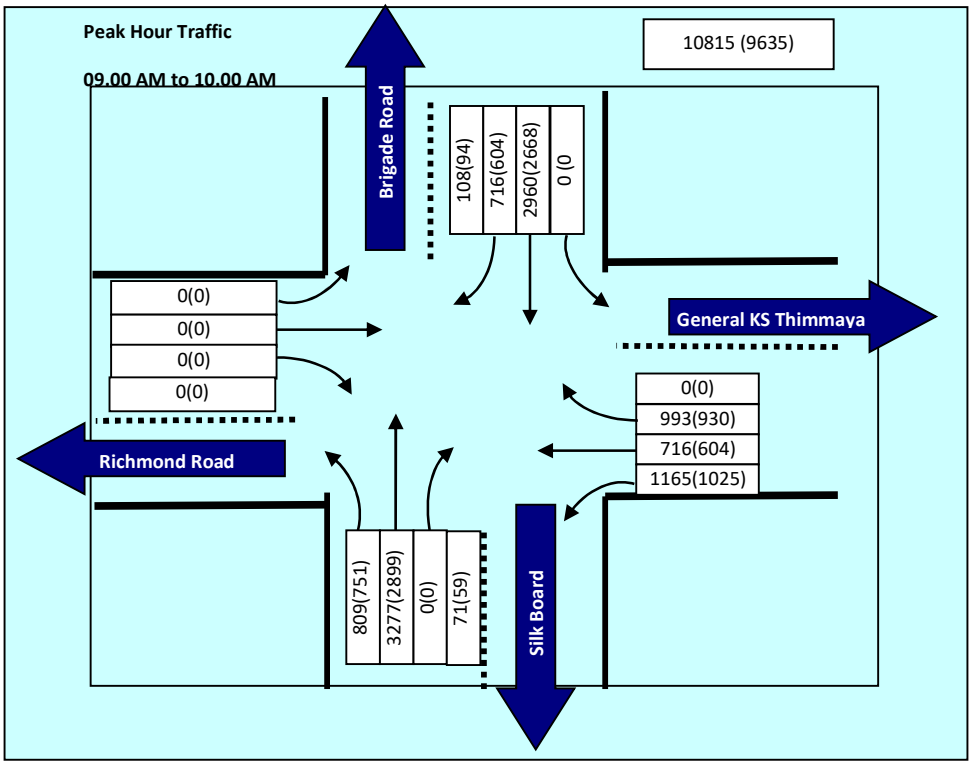

Figure 1.4 Peak Hour Traffic at Shooley Junction

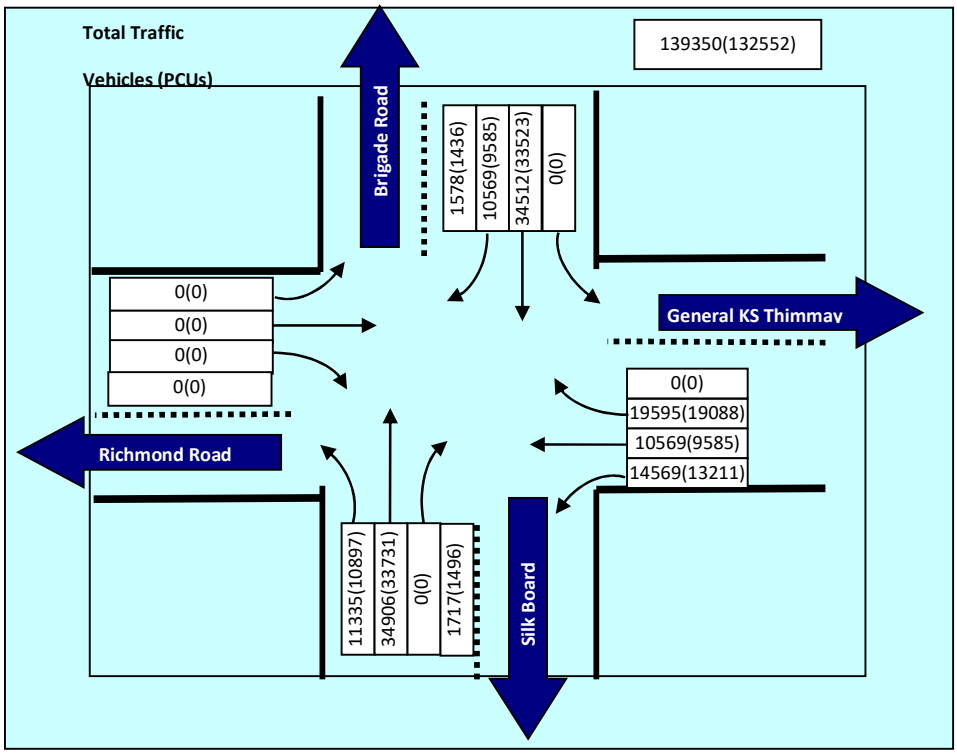

Figure 1.5 Total Traffic at Shooley Junction

1.6.2 TMC 02 (Adugodi Junction)

- A total of about 1,24,095 vehicles (1,15,734 PCU's) pass at this location per 24 Hours.
- Goods vehicles account for 5.33% and passenger vehicles account for 94.55% of the total traffic. Non-motorized traffic constitutes about 0.11% of total vehicles.
- Among the passenger vehicles, two wheelers and cars are the dominant ones constituting about 53.55% and 26.76%. Whereas Auto Rickshaw and buses (Minibus, Pvt. Bus, Govt. Bus) are at 14.25%.
- Morning Peak Hour at 09.00 AM to 10.00 AM (6.97%, Peak Hour Factor) and Evening Peak Hour at 18.00 PM to 19.00 PM (6.13%, Peak Hour Factor).

Figure 1.6 and **Figure 1.7** shows Traffic Composition and hourly variation of traffic at location. Direction-wise Flow diagram is given in **Figure 1.8** to **Figure 1.9.**

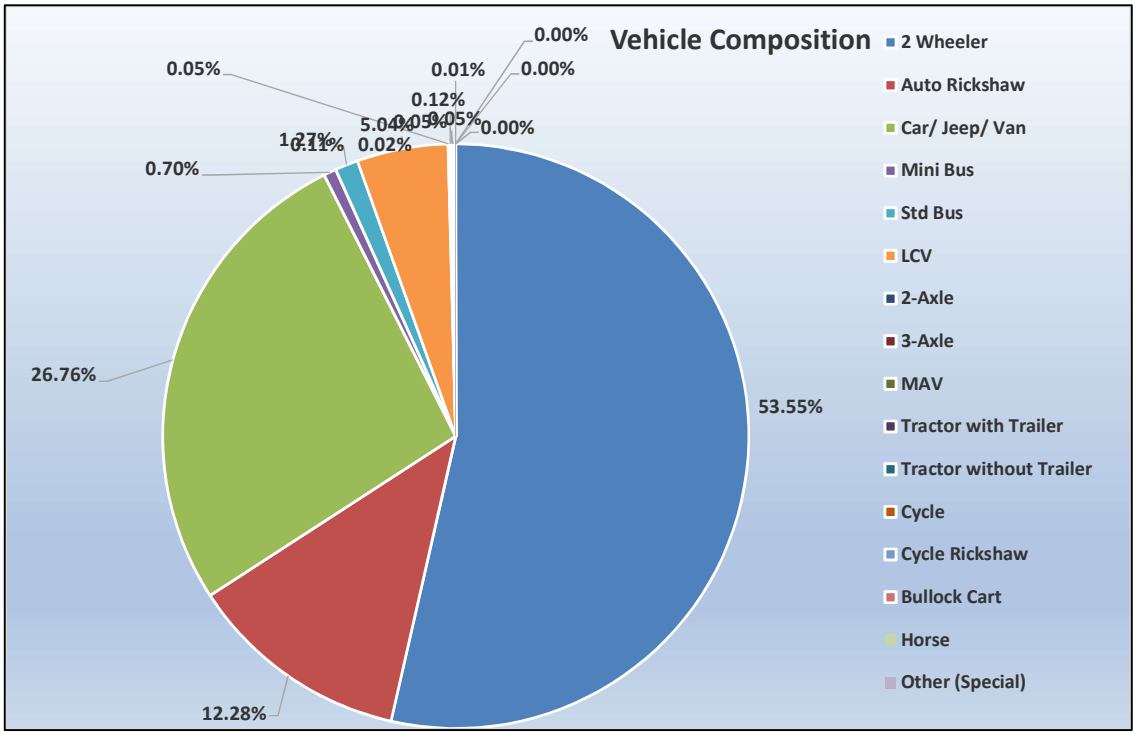

Figure 1.6 Traffic Composition at Adugodi Junction

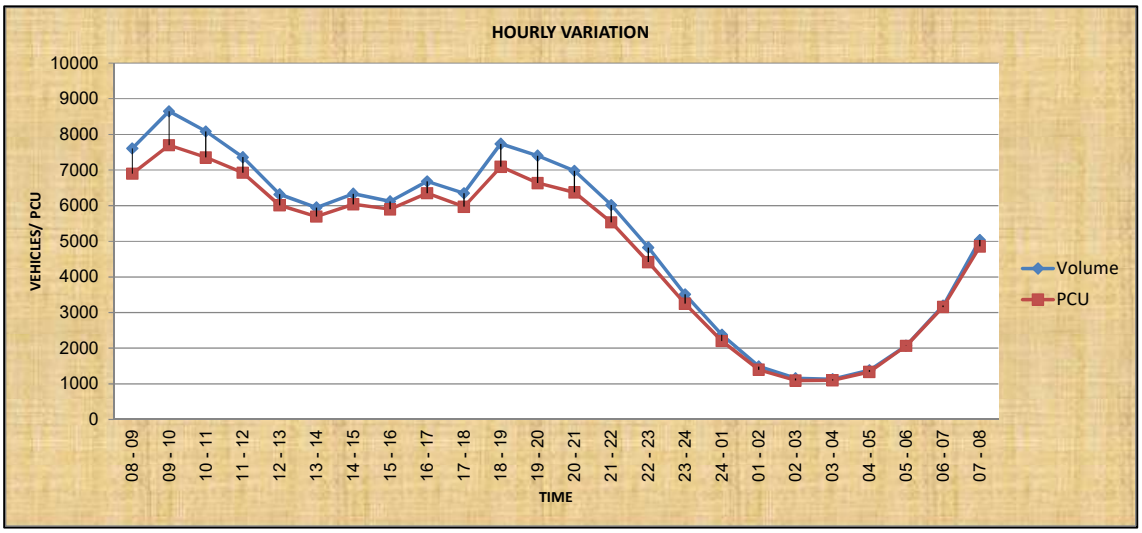

Figure 1.7 Hourly Traffic at Adugodi Junction

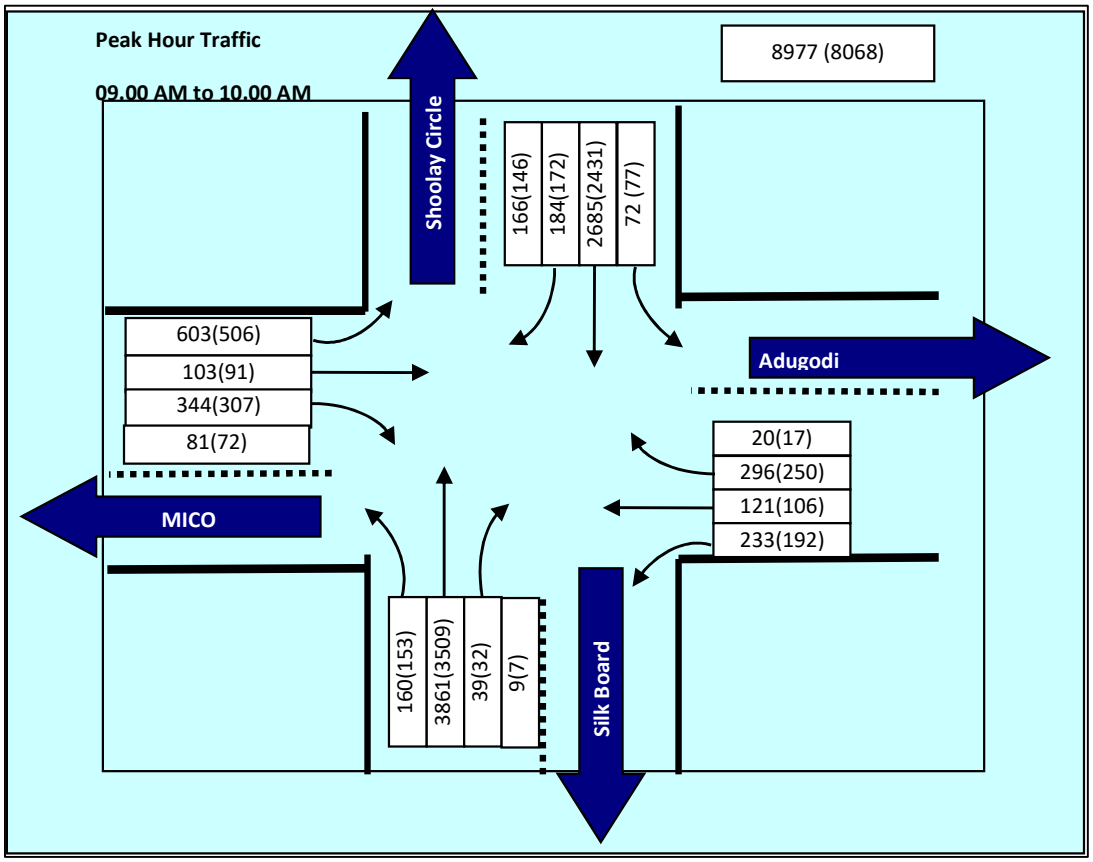

Figure 1.8 Peak Hour Traffic at Adugodi Junction

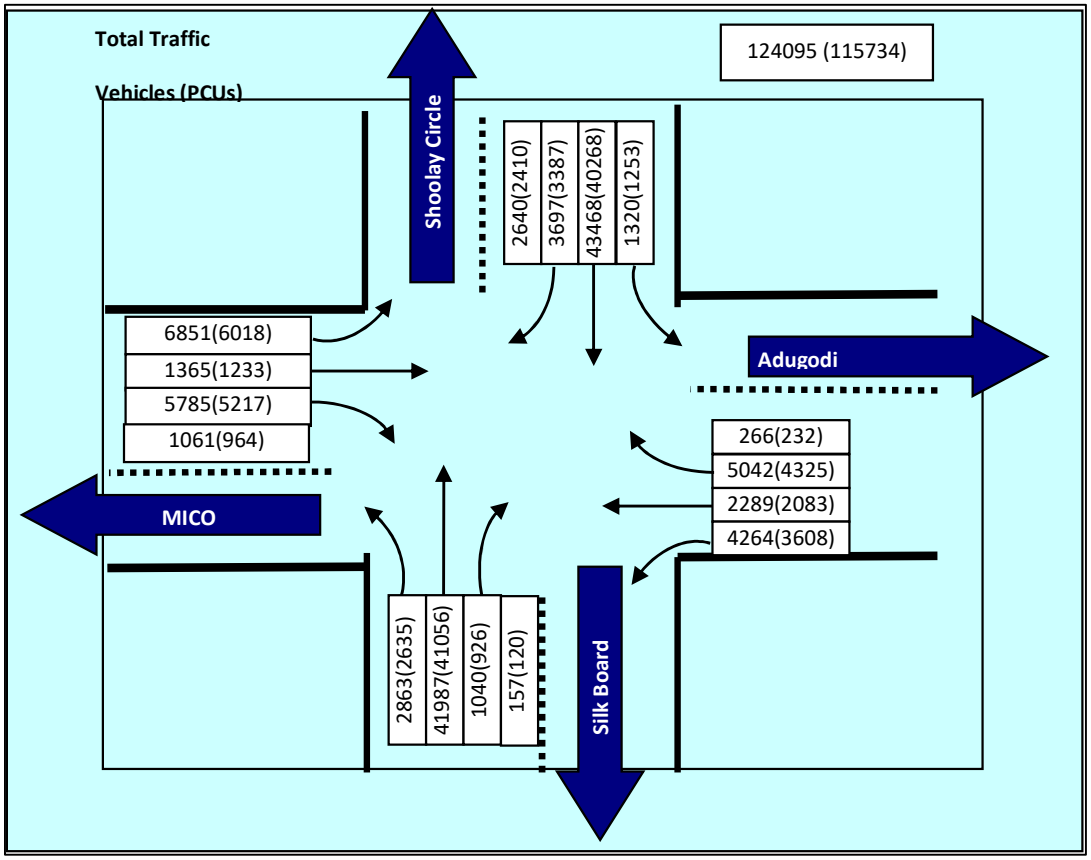

Figure 1.9 Total Traffic at Adugodi Junction

1.6.3 TMC 03 (St John's Hospital Junction)

- A total of about 2,17,257 vehicles (2,06,267 PCU's) pass at this location per 24 Hours.
- Goods vehicles account for 5.34% and passenger vehicles account for 94.54% of the total traffic. Non-motorized traffic constitutes about 0.12% of total vehicles.
- Among the passenger vehicles, two wheelers and cars are the dominant ones constituting about 50.95% and 28.65%. Whereas Auto Rickshaw and buses (Minibus, Pvt. Bus, Govt. Bus) are at 14.94%.
- Morning Peak Hour at 09.00 AM to 10.00 AM (6.36%, Peak Hour Factor) and Evening Peak Hour at 19.00 PM to 20.00 PM (5.87%, Peak Hour Factor).

Figure 1.10 and **Figure 1.11** shows Traffic Composition and hourly variation of traffic at location. Direction-wise Flow diagram is given in **Figure 1.12** to **Figure 1.13.**

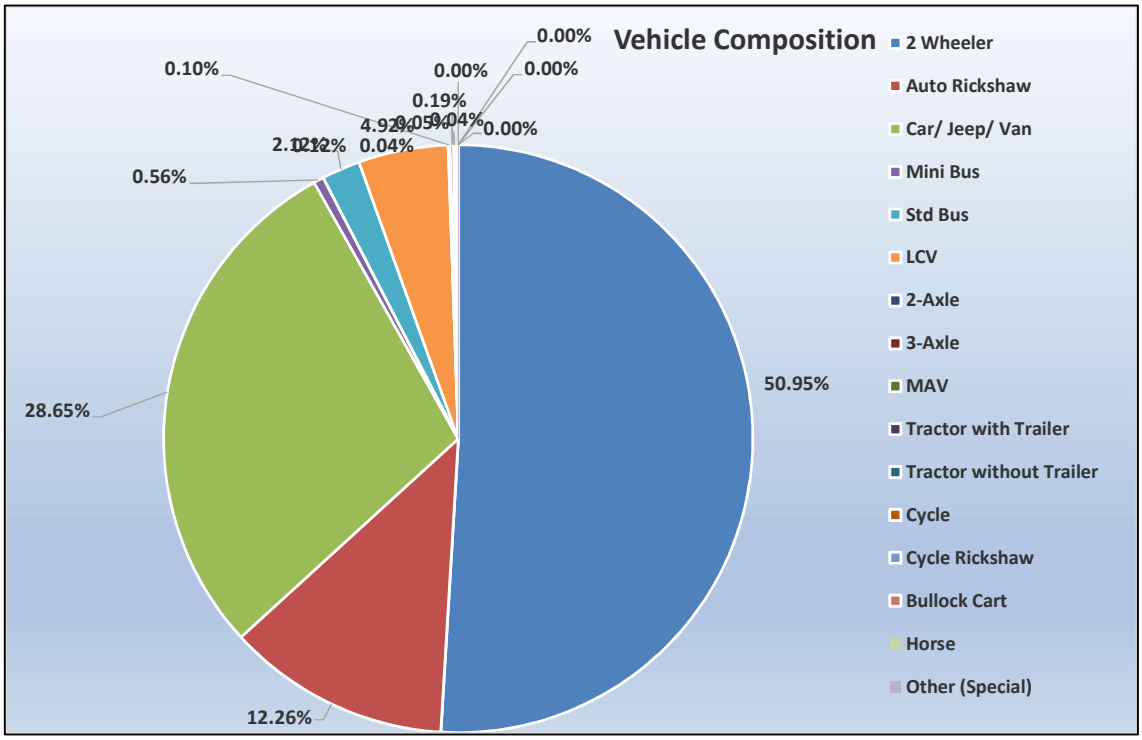

Figure 1.10 Traffic Composition at St John's Hospital Junction

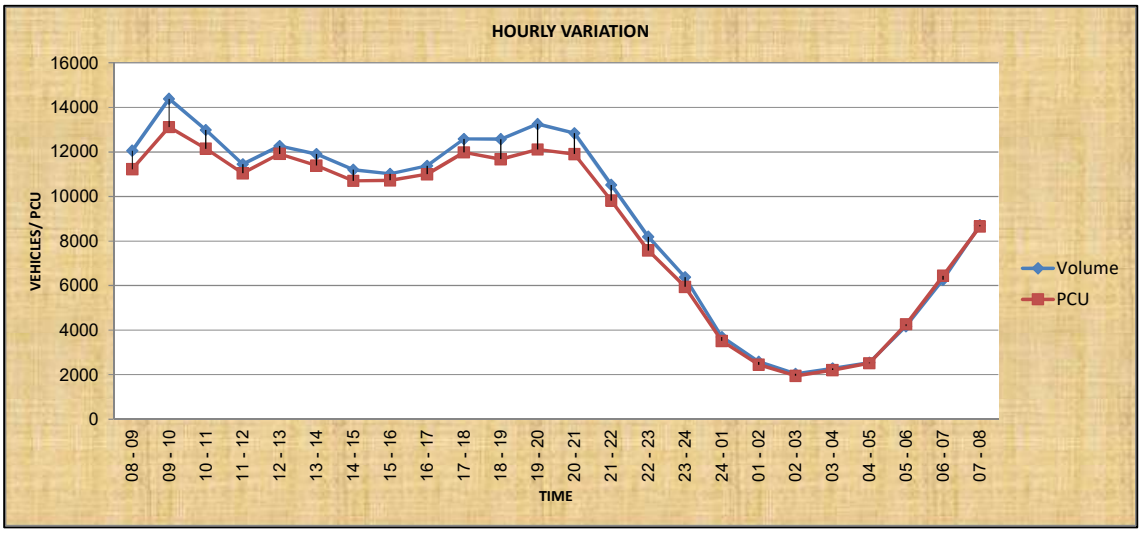

Figure 1.11 Hourly Traffic at St John's Hospital Junction

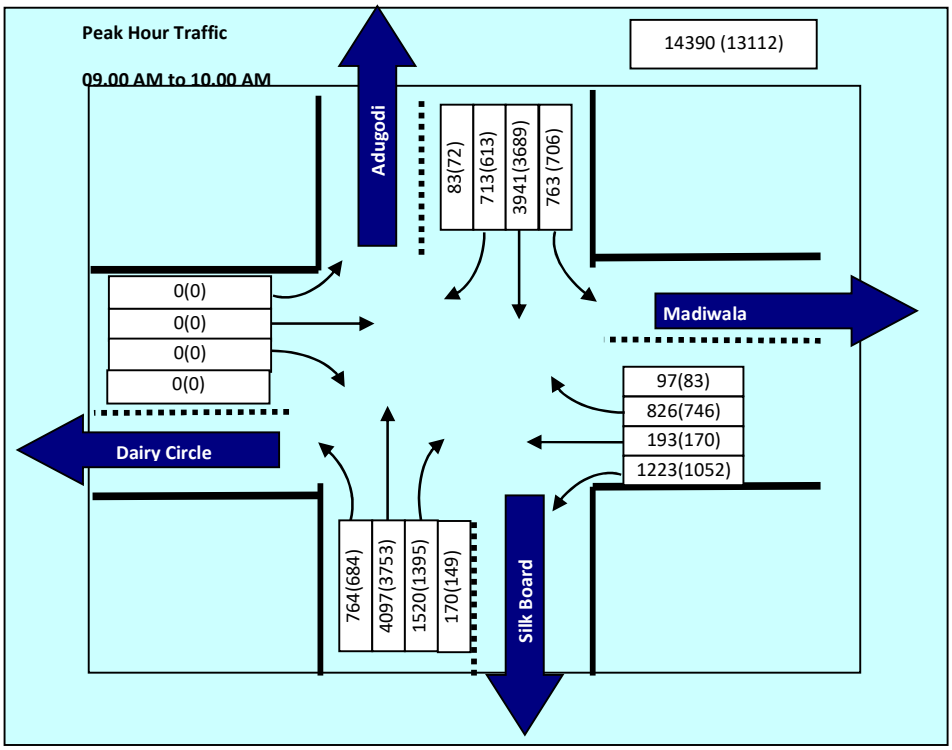

Figure 1.12 Peak Hour Traffic at St John's Hospital Junction

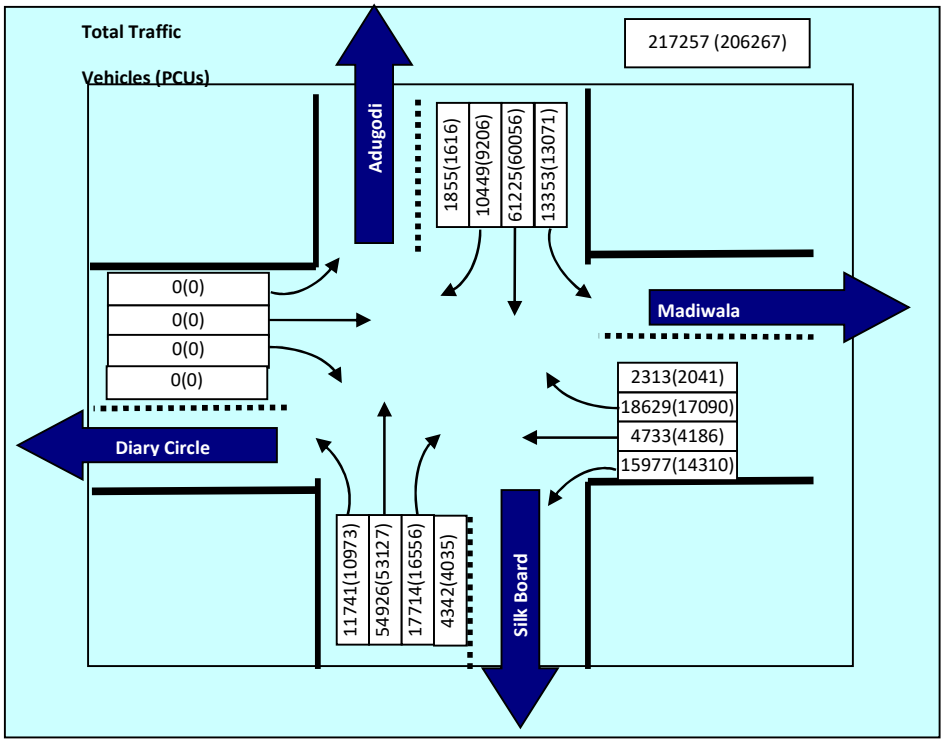

Figure 1.13 Total Traffic at St John's Hospital Junction

1.6.4 Justification/warrants for grade separators or interchanges

As per clause 5.10.4 of IRC: SP: 90-2010 and as per clause 4.5.6 of IRC: 92-2017, Grade Separators or Interchanges, in general, are expensive to construct and a major factor influencing the cost is the type of arrangement made for the various traffic movement. The arrangement may range from separating only one traffic movement from other to the complete separation of each traffic movement from every other movement, so that only merging and diverging movements remain. Similarly, the vehicle operating cost will vary depending on the type of ramp arrangement, from direct conflict-free connections to indirect connections involving extra travel distance. However, the following points may be helpful in guiding the choice of an interchange at the preliminary planning stage:

1. Interchanges will be required at all major crossings on highways developed to expressway standards.
2. An interchange may be justified at the crossing of a major arterial road with another road of similar category carrying heavy traffic.
3. An interchange may be justified when an at grade intersection fails to handle the volume of traffic resulting in serious congestion and frequent choking of the inter-section. This situation may arise when the total traffic of all the arms of the intersection is in excess of 10,000 PCU's per hour.
4. High and disproportionate rate of fatal and major accidents at an interaction not found to respond to other traffic control or improvement measure may warrant an interchange.
5. In some situations, the topography is such that interchanges are the only type that can be constructed economically.
6. The requirement of interchange may also be justified from the existing constraints of the junctions other than traffic volume like parking, market, important and religious structures, buildings with frequent crowding.
7. While planning interchange at a particular location the traffic requirements of the entire road on both sides should be taken into account.

1. Shooley Junction

The Shooley junction is formed by 3 roads, Hosur Road, General K S Thimmayya Road and Richmond Road. The present peak hour capacity of the junction is **9635**

PCUs per Hour. This junction exceeds **10,000 PCUs** per Hour in year **2026** which warrants for grade separation as per clause 5.10.4 of IRC: SP: 92-2010 and as per clause 4.5.6 of IRC: 92-2017.

Table 1.3 Peak Hour traffic details for Shooley Junction

Peak Hour	Total	YEARS											
		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Morning	Vehicles	10815	**11601**	12444	13349	14319	15360	16477	17674	18959	20337	21816	23401
	PCUs	9635	**10335**	11087	11893	12757	13684	14679	15746	16891	18118	19435	20848
Evening	Vehicles	8599	**9112**	9656	10232	10842	11489	12175	12901	13671	14486	15351	16267
	PCUs	7909	**8380**	8880	9410	9972	10567	11197	11865	12573	13323	14118	14960

2. Adugodi Junction

The Adugodi junction is formed by 3 roads, Hosur Road, New MICO Road and Adugodi Road. The present peak hour capacity of the junction is **7701 PCUs per** This junction exceeds **10,000 PCUs** per Hour in year **2029** the capacity which warrants for grade separation as per clause 5.10.4 of IRC: SP: 92-2010 and as per clause 4.5.6 of IRC: 92-2017.

Table 1.4 Peak Hour traffic details for Adugodi Junction

Peak Hour	Total	YEARS											
		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Morning	Vehicles	8977	9603	10272	10988	**11754**	12574	13450	14388	15390	16463	17611	18839
	PCUs	8068	8630	9231	9875	**10563**	11300	12087	12930	13831	14795	15827	16930
Evening	Vehicles	7738	8212	8715	9249	**9816**	10417	11055	11733	12451	13214	14024	14883
	PCUs	7090	7525	7986	8475	**8994**	9545	10130	10751	11409	12108	12850	13638

3. St John's Hospital Junction

The St John's Hospital junction is the major junction at the Hosur road. The present peak hour capacity of the junction is **13112 PCUs per Hour** which is more than **10,000 PCUs** per Hour which warrants for grade separation as per clause 5.10.4 of IRC: SP: 92-2010 and as per clause 4.5.6 of IRC: 92-2017.

Table 1.5 Peak Hour traffic details for St John's Hospital Junction

Peak Hour	Total	YEARS											
		2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Morning	Vehicles	14390	15305	16278	17312	18413	19583	20828	22152	23560	25058	26651	28345
	PCUs	13112	13946	14832	15775	16778	17844	18979	20185	21468	22833	24284	25828
Evening	Vehicles	13252	14030	14854	15725	16649	17626	18661	19756	20916	22144	23443	24820
	PCUs	12108	12819	13572	14368	15212	16105	17050	18051	19111	20233	21420	22678

As per the above traffic data, the traffic at most junctions exceeded the capacity which warrants for grade separator facility or will exceed within the next 3 years and become bottleneck in near future. This indicates the requirement of alternative solutions to overcome this problem in terms of grade separators at the junctions.

1.7 ORIGIN AND DESTINATION SURVEY & ANALYSIS

Origin Destination (O-D) survey was conducted at two locations for this project. Location 01 is at Adugodi junction and Location 02 is St. John's Hospital junction. The main scope of this work is to arrive the diverted traffic to proposed elevated corridor based on the outcome of the surveys and forecast using standard growth rate of 5%.

Origin Destination (O-D) survey, as detailed in IRC: 102-1988, was adopted. The survey was carried out for both passenger and goods vehicles for peak hours (morning and evening) (in all directions at the junction) on a working day. For this purpose, cars, mini buses and buses (Govt. Bus and Pvt. Bus) were considered as passenger vehicles. Similarly, LCVs, 2-Axle Trucks, 3-Axle Trucks, 4-6 Axle Trucks and >=7-Axle Trucks were considered as goods vehicles. Trained enumerators under the supervision of Traffic Engineers collected the travel information.

The information collected contained trip origin and trip destination. In addition, type of commodity for goods vehicles and purpose and occupancy for passenger vehicles were also collected.

1.7.1 Sample Size and Expansion Factors

The vehicles during O-D surveys were interviewed on a random sample basis. Based on the sample size of different categories of vehicles interviewed during survey, expansion factors were calculated for the expansion of O-D matrices generated from the sample data to make assessment of the travel patterns of vehicles. The following **Table 1.6** shows sample size and expansion factors.

Table 1.6 Sample Size and Expansion Factors

Vehicle Type	O - D Sample size (Nos)	Peak Hour Volume count data (Nos)	Volume count data (Nos)	Expansion factors	% of sample collected
	A	B	C	B/A	A/C
Adugodi Junction					
Car	551	7041	7041	12.78	7.83%
Minibus	29	193	193	6.66	15.03%
Bus	90	336	336	3.73	26.79%
Auto Rickshaw	415	3825	3825	9.22	10.85%

Vehicle Type	O - D Sample size (Nos)	Peak Hour Volume count data (Nos)	Volume count data (Nos)	Expansion factors	% of sample collected
	A	B	C	B/A	A/C
Two Wheelers	2876	19317	19317	6.72	14.89%
LCV	135	1099	1099	8.14	12.28%
2 AXLES	2	2	2	1.00	100.00%
3 AXLES	3	3	3	1.00	100.00%
MAV	0	0	0	0.00	0.00%
TOTAL	**4101**	**31816**	**31816**		
St. John's Hospital Junction					
Car	711	13403	13403	18.85	5.30%
Minibus	21	211	211	10.05	9.95%
Bus	188	1026	1026	5.46	18.32%
Auto Rickshaw	588	6155	6155	10.47	9.55%
Two Wheelers	3144	30343	30343	9.65	10.36%
LCV	103	1961	1961	19.04	5.25%
2 AXLES	8	14	14	1.75	57.14%
3 AXLES	13	14	14	1.08	92.86%
MAV	0	0	0	0.00	0.00%
TOTAL	**4776**	**53127**	**53127**		

1.7.2 Zoning System

The area adjacent to the project road, which contributes most of the trips observed on the project road, constitutes IIA, whereas, other localities of Bengaluru and other region in the country constitute BIA. In all, **46 zones** were defined for the project.

The adopted zoning scheme has been given in **Table 1.7**.

Table 1.7 Zoning Scheme for the project

Zone No	Zone Name	State
1	MG Road, Church Street, Museum Road, Kamaraj Road	Karnataka

Zone No	Zone Name	State
2	Residency Road, Cubbon Road, Ashok Nagar	Karnataka
3	Shivaji Nagar, Queens Road	Karnataka
4	Bangalore Cant, Vasanth Nagar, Millers Road	Karnataka
5	Ambedkar Road, Vidhana Soudha, High Court, Palace Road	Karnataka
6	Majestic, Gandhi Nagar	Karnataka
7	UB City, Kasturba Road, Lavelle Road, St Marks Road, Cubbon Park, Mallya Road, Manipal Hospital	Karnataka
8	Richmond Town, Richmond Road, Johnson Market, Vellara Junction	Karnataka
9	Shanti Nagar, Langford Road, Longford Town, Wilson Garden, Double Road, KH Road	Karnataka
10	Neelasandra, CMP Centre, Muniswamy Garden, Austin Town, Anepalya	Karnataka
11	Anepalya, Adugodi	Karnataka
12	Koramangala, Ejipura	Karnataka
13	Jayanagar, Lalbagh, Byrasandra	Karnataka
14	New MICO Road, Lakkasandra	Karnataka
15	Hombegowda Nagar, Diary Circle, Christ University, Christ School, Narayana Hrudayalaya	Karnataka
16	Forum Koramangala, Hosur Road	Karnataka
17	St John's Hospital	Karnataka
18	Madiwala, Silk Board, Jakkasandra	Karnataka
19	Tavarekere, Maruti Nagar	Karnataka
20	Venkatapura, HSR Layout, Sarjapura, Agara, BTM Layout	Karnataka
21	Kottigepalya, Magadi Road, Laggere	Karnataka
22	Jayadeva Hospital, Marenahalli Road, JP Nagar 3rd Phase	Karnataka
23	Bommanahalli, Kudlu Gate, De Mart, Garvebhavipalya, Mangammanapalya, Roopena Agrahara, Somasunderpalya	Karnataka
24	Electronic City, NICE Road, Attibele, Chandapura, Anekal, Begur, Mylasandra, VishwaPriya Layout, Konappa Agrahara, Oxford Hospital	Karnataka
25	Bommasandra, Gottigere, Hebbagodi, Huskur Gate, Wipro Gate	Karnataka
26	Hongasandra, MICO Layout	Karnataka
27	Banashankari, JP Nagar 5th Phase	Karnataka

Zone No	Zone Name	State
28	Bilekahalli, Hulimavu, Accenture, Bannerghatta, Arekere	Karnataka
29	Hebbala, Airport, Yelahanka, Allasandra, Nagavara, Kodigehalli	Karnataka
30	AECS Layout, Singasandra, Hosapalya, Muneshwara Nagar, Parappana Agrahara, Hosa Road	Karnataka
31	JP Nagar 8th Phase, Kothnur, JP Nagar 7th Phase	Karnataka
32	Kanakapura Road, Uttarahalli	Karnataka
33	Vajarahalli, Anjanapura	Karnataka
34	Chamarajapet, Basavanagudi, Bull Temple Road, Gandhi Bazar, National College	Karnataka
35	Giri Nagar, Hanumanthnagar, Katriguppe, N R Colony	Karnataka
36	Nayandahalli, Deepanjali Nagar, Kengeri, Banashankari 3rd Stage, Ittamadu, Hosakerehalli, Manjunath Nagar, Bandepalya, Kuvempu Nagar, PES College	Karnataka
37	Bellary Road, CV Raman Nagar, Yeshwanthpur, Guttahalli, Dasarahalli, Nagasandra	Karnataka
38	Jayamahal, Coles Park, RT Nagar	Karnataka
39	Frazer Town, Cox Town	Karnataka
40	Baiyappanahalli, KR Puram, HBR Layout	Karnataka
41	Indiranagar, Domlur	Karnataka
42	HAL, Marathahalli, Whitefield, Belur, Bellandur, Varthur, Mahadevpura	Karnataka
43	Bellandur, Kadubeesanahalli	Karnataka
44	K R Market, K R Circle, Town Hall, Kalasipalya, S P Road, Chickpet, Binnipet, Corporation, Cottonpete, UVCE, KR Circle, S P Road, SJP Road	Karnataka
45	Vijayanagar, Rajaji Nagar, Navarang, Sheshadripuram, Shivananda Circle	Karnataka
46	Hosur, Selam, Dharmapuri, TN	Tamil Nadu

1.7.3 Expansion factors and development of O – D matrices

The origin – destination details were collected from the trip makers during the survey on sample basis. Sampling varied with the changes in traffic flow across the day. Care has been taken to eliminate any element of bias in sampling. Since data was collected on sample basis, expansion factors are required to replicate the pattern as reflected in the sample to the total number of vehicular trips made during the day. These expansion

factors are calculated separately for each class of vehicle and direction wise. For example, if xc is number of cars interviewed and Xc is the total number of cars counted during the day, then Xc/xc would be the expansion factor for cars.

O – D matrices are developed to assess the traffic movement pattern. These matrices actually speak about distribution of trips for each zone as intra-zonal and inter-zonal movements. The vehicle wise O – D matrices are developed by multiplying the sample O – D matrix obtained from survey data with expansion factors. Accordingly, matrices for different modes were developed.

1.7.4 Zone Influence Factors

The data collected from O-D survey were coded and entered according to the zoning system described above and the O-D matrices were prepared. The movements of the vehicles (in %) in the project influence area is summarized below:

Zone Influence Factors:

$IF = [(Pi + Ai) \times 100] / (\sum (Pi + Ai))$

Where,

IF = Influence Factor
Pi = Total trips produced in Zone i
Ai = Total trips attracted in Zone i

Table 1.8 Region wise Influence factors estimated from O-D matrices – Adugodi Junction

Zone No.	Vehicle Type								
	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	MAV
1	13.16	3.45	1.67	4.10	5.77	6.67	0.00	16.67	0.00
2	2.63	5.17	2.78	0.96	0.43	0.00	0.00	0.00	0.00
3	0.73	0.00	7.22	2.05	0.54	0.00	25.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	3.99	6.90	17.78	4.22	2.28	2.59	0.00	0.00	0.00
7	3.54	3.45	1.11	2.53	1.62	0.37	0.00	16.67	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	4.17	1.72	5.00	5.42	6.54	3.33	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Zone No.	Vehicle Type								
	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	MAV
11	2.09	12.07	3.89	4.58	5.09	2.59	0.00	0.00	0.00
12	7.99	5.17	3.33	10.12	4.80	5.19	0.00	0.00	0.00
13	2.36	0.00	0.56	1.57	0.78	3.33	0.00	0.00	0.00
14	0.27	1.72	0.56	0.00	0.00	1.11	0.00	0.00	0.00
15	0.82	0.00	0.00	0.84	0.54	0.74	0.00	0.00	0.00
16	4.26	3.45	4.44	4.10	2.24	2.22	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	3.56	0.00	0.00	0.00	0.00
18	8.80	10.34	5.56	10.12	13.51	12.22	25.00	16.67	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	7.62	15.52	1.67	5.90	5.65	3.33	0.00	16.67	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.63	0.00	0.00	0.00	0.00
23	5.44	8.62	8.33	4.70	4.21	13.33	0.00	0.00	0.00
24	11.52	3.45	21.67	7.95	13.04	5.93	0.00	16.67	0.00
25	2.54	0.00	5.00	1.57	2.00	4.44	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	1.09	0.00	0.00	3.25	1.77	1.11	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.09	1.72	1.11	0.60	0.73	1.85	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.09	0.00	0.00	0.12	0.00	0.37	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	1.09	0.00	0.00	2.41	1.22	0.00	0.00	0.00	0.00
37	2.00	1.72	0.56	1.81	0.45	0.00	0.00	16.67	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Zone No.	Vehicle Type								
	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	MAV
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	2.54	0.00	0.00	2.29	0.61	0.00	0.00	0.00	0.00
42	2.09	0.00	0.00	4.22	0.56	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	8.62	15.52	7.78	14.22	21.42	29.26	25.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.45	0.00	0.00	0.36	0.02	0.00	25.00	0.00	0.00
Total	100	100	100	100	100	100	100	100	0!

Passenger Vehicles: The analysis of travel pattern for passenger vehicles reveals that all the trips are within Bangalore south and its influence area.

Commercial Vehicles: Above data shows that majority of the freight traffic including LCV, 2 Axle, 3 Axle and MAV trucks are travelling majorly within the Bangalore urban limits.

Table 1.9 Region wise Influence factors estimated from O-D matrices – St John's Hospital Junction

Zone No.	Vehicle Type								
	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	MAV
1	7.31	2.38	0.00	4.68	6.97	0.00	0.00	0.00	0.00
2	2.74	2.38	1.33	4.76	3.18	0.00	0.00	0.00	0.00
3	3.23	0.00	0.80	2.98	0.52	0.00	0.00	0.00	0.00
4	2.25	0.00	0.00	2.72	0.06	0.00	0.00	0.00	0.00
5	0.07	0.00	0.00	1.87	0.03	0.00	0.00	0.00	0.00
6	8.65	0.00	6.65	10.46	3.29	7.77	12.50	3.85	0.00
7	0.63	0.00	0.00	0.09	1.16	0.00	0.00	0.00	0.00
8	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	5.41	4.76	4.79	4.68	5.80	3.88	12.50	0.00	0.00
10	0.07	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	1.06	0.43	1.30	3.88	0.00	0.00	0.00

Zone No.	Vehicle Type								
	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	MAV
12	1.48	0.00	4.79	0.17	2.10	5.83	0.00	3.85	0.00
13	0.00	4.76	2.13	0.00	0.91	1.94	0.00	0.00	0.00
14	0.28	2.38	2.13	0.00	0.00	0.00	0.00	0.00	0.00
15	0.98	0.00	0.80	0.00	0.43	0.97	0.00	3.85	0.00
16	1.97	7.14	1.06	1.62	1.21	1.94	0.00	3.85	0.00
17	0.00	0.00	0.00	0.26	3.28	0.00	0.00	0.00	0.00
18	5.49	7.14	5.59	6.04	11.78	0.00	12.50	0.00	0.00
19	0.35	0.00	0.53	0.00	0.10	0.00	0.00	0.00	0.00
20	12.10	4.76	9.84	20.41	8.24	23.30	18.75	0.00	0.00
21	0.42	0.00	0.00	0.51	0.65	0.00	0.00	0.00	0.00
22	0.91	0.00	0.00	1.19	1.53	0.00	0.00	0.00	0.00
23	5.13	2.38	8.78	2.98	4.28	3.40	18.75	0.00	0.00
24	11.74	19.05	12.77	7.14	12.66	6.80	6.25	15.38	0.00
25	2.53	4.76	1.06	2.38	1.89	0.00	0.00	0.00	0.00
26	0.91	0.00	0.27	0.94	1.10	0.00	0.00	0.00	0.00
27	1.83	4.76	0.27	2.55	1.86	3.88	0.00	3.85	0.00
28	0.63	0.00	0.00	0.09	0.08	0.00	0.00	0.00	0.00
29	1.83	0.00	0.27	0.51	1.32	0.97	0.00	0.00	0.00
30	0.21	0.00	0.00	0.34	0.10	0.97	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
33	0.49	2.38	0.00	1.02	0.17	0.97	0.00	0.00	0.00
34	4.92	4.76	2.39	4.17	0.94	4.85	12.50	7.69	0.00
35	0.77	0.00	0.80	0.51	0.24	0.00	0.00	0.00	0.00
36	1.83	7.14	3.99	2.13	0.92	4.85	0.00	0.00	0.00
37	0.28	2.38	0.53	0.17	0.24	0.00	0.00	0.00	0.00
38	0.07	0.00	0.00	0.17	0.11	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	3.02	2.38	1.06	2.30	0.83	0.00	6.25	3.85	0.00

Zone No.	Vehicle Type								
	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	MAV
41	0.42	0.00	0.00	0.43	0.60	1.94	0.00	0.00	0.00
42	3.66	2.38	4.79	1.28	1.75	11.65	0.00	26.92	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	4.01	7.14	14.89	6.72	18.16	9.22	0.00	15.38	0.00
45	0.28	0.00	0.80	0.43	0.05	0.00	0.00	0.00	0.00
46	0.98	4.76	5.59	0.94	0.13	0.97	0.00	11.54	0.00
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**0!**

Passenger Vehicles: The analysis of travel pattern for passenger vehicles reveals that all the trips are within Bangalore south and its influence area.

Commercial Vehicles: Above data shows that majority of the freight traffic including LCV, 2 Axle, 3 Axle and MAV trucks are travelling majorly within the Bangalore urban limits.

1.7.5 Proposal for Hosur Road

The proposal for reducing congestion on existing Hosur road from Shooley junction to St John's Hospital junction consists of 2 lane undivided grade separator at Shooley junction and 4-lane divided grade separator connecting Adugodi junction and St John's Hospital junction including 2 lane entry/exit ramps to Madiwala direction.

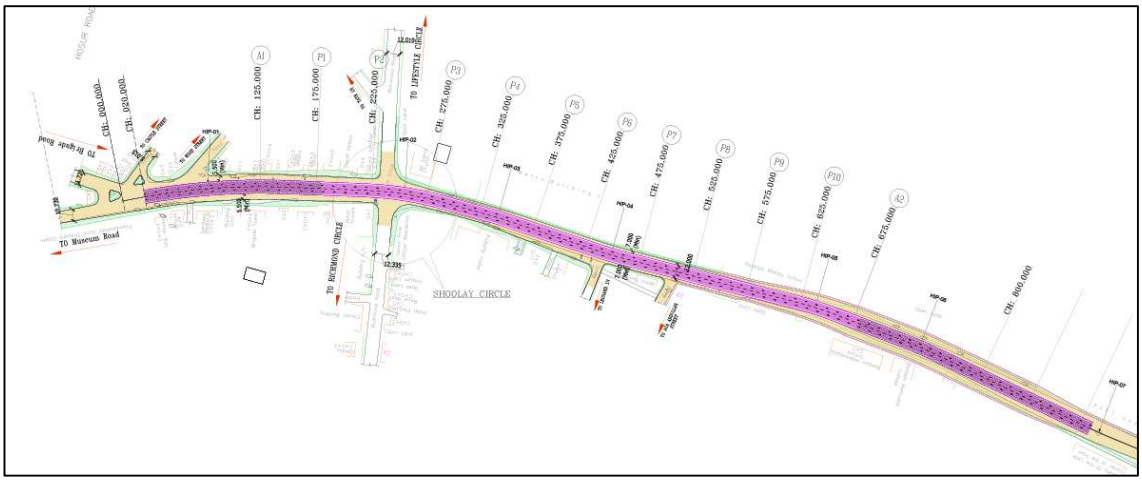

Figure 1.14 Grade separator proposal at Shooley Junction

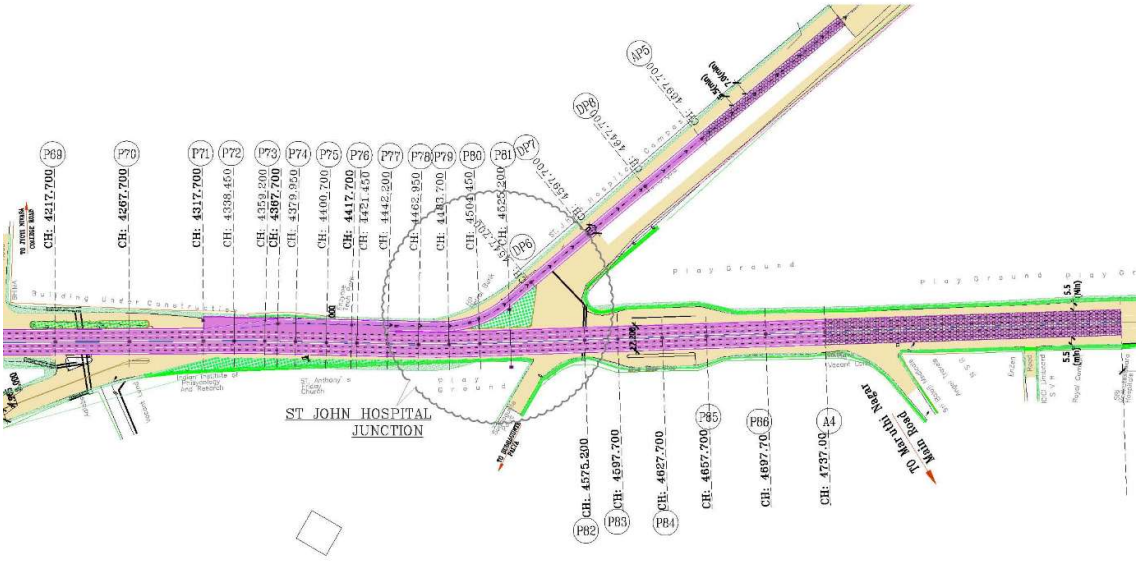

Figure 1.15 Grade separator proposal at St John's Hospital Junction

The existing traffic movement is studied to obtain traffic on these proposed grade separators. Origin and Destination surveys along with turning movement surveys are carried out calculate the diverted traffic on these 2 grade separators. The proposed entry ramp from Madiwala direction towards Adugodi is now being removed from the scope.

1.7.6 DIVERTED TRAFFIC – SHOOLEY JUNCTION

The diverted traffic for proposed grade separator at Shooley junction will be calculated from the existing traffic movement between Bridge road to Adugodi and origin & destination survey carried out at Adugodi junction. The intention of carrying out Origin and Destination was to study the existing travel pattern and calculate the traffic which can be diverted to proposed grade separator. This assessment is carried out for Cars, Two-Wheelers and commercial vehicles like LCVs, 2 Axle, 3 Axle and Multi Axle Trucks. Buses are excluded from these calculations as these categories of vehicles will follow existing routes.

Table 1.10 Diverted traffic – Shooley Junction

Vehicle Type	Percentage of Traffic to Grade Separator	Existing	Grade Separator	At Grade	Existing	Grade Separator	At Grade
		Brigade Road to Silk Board			Silk Board to Brigade Road		
2 Wheeler	37.30%	1981	739	1242	2264	844	1420

Vehicle Type	Percentage of Traffic to Grade Separator	Existing	Grade Separator	At Grade	Existing	Grade Separator	At Grade
		Brigade Road to Silk Board			Silk Board to Brigade Road		
Auto Rickshaw	18.10%	358	65	293	313	57	256
Car/ Jeep/ Van	43.40%	459	199	260	547	237	310
Mini Bus	48.30%	10	5	5	4	2	2
Std. Bus	0.00%	89	0	89	86	0	86
LCV	12.60%	59	7	52	56	7	49
2 Axle	0.00%	0	0	0	1	0	1
3 Axle	0.00%	0	0	0	0	0	0
MAV	0.00%	0	0	0	0	0	0
Tractor with Trailer	0.00%	0	0	0	0	0	0
Tractor without Trailer	0.00%	0	0	0	1	0	1
Cycle	0.00%	4	0	4	5	0	5
Cycle Rickshaw	0.00%	0	0	0	0	0	0
Bullock Cart	0.00%	0	0	0	0	0	0
Horse	0.00%	0	0	0	0	0	0
Other (Special)	0.00%	0	0	0	0	0	0

1.7.7 Diverted Traffic – St John's Hospital Junction

The diverted traffic for proposed grade separator at St John's Hospital junction will be calculated from the existing traffic movement at the junction and origin & destination survey. The intention of carrying out Origin and Destination was to study the existing travel pattern and calculate the traffic which can be diverted to proposed grade separator. This assessment is carried out for Cars, Two-Wheelers, Auto Rickshaw, Mini buses and commercial vehicles like LCVs, 2 Axle, 3 Axle and Multi Axle Trucks. Buses are excluded from these calculations as these categories of vehicles will follow existing routes. **Table 1.11** gives the tentative origin and destination zones from which the traffic can be diverted.

Table 1.11 Diversion of Traffic from Zones

From (Zones)	To (Zones)
1	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46

From (Zones)	To (Zones)
2	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
3	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
4	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
5	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
6	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
7	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
8	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
9	18, 20, 22, 23, 24, 25, 26, 27, 28, 31, 32, 33, 43, 46
10	
11	
12	
13	
14	
15	
16	
17	
18	1, 2, 3, 4, 5, 6, 7, 8, 9
19	
20	1, 2, 3, 4, 5, 6, 7, 8, 9
21	
22	1, 2, 3, 4, 5, 6, 7, 8, 9
23	1, 2, 3, 4, 5, 6, 7, 8, 9
24	1, 2, 3, 4, 5, 6, 7, 8, 9
25	1, 2, 3, 4, 5, 6, 7, 8, 9
26	1, 2, 3, 4, 5, 6, 7, 8, 9
27	1, 2, 3, 4, 5, 6, 7, 8, 9
28	1, 2, 3, 4, 5, 6, 7, 8, 9

From (Zones)	To (Zones)
29	
30	
31	1, 2, 3, 4, 5, 6, 7, 8, 9
32	1, 2, 3, 4, 5, 6, 7, 8, 9
33	1, 2, 3, 4, 5, 6, 7, 8, 9
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	1, 2, 3, 4, 5, 6, 7, 8, 9
44	
45	
46	1, 2, 3, 4, 5, 6, 7, 8, 9

The diverted traffic to the proposed grade separator is calculated using the O-D matrix. Diverted traffic is given in **Table 1.12** and **Table 1.13** below. The diverted traffic are calculated separately for through traffic and traffic which may use entry/exit ramp near.

The diverted traffic per hour is calculated by using peak hour traffic obtained from turning movement survey at particular Origin and Destination locations. Total traffic given in above tables are multiplied with peak hour factor to obtain peak hour traffic. This diverted traffic in terms of peak hour traffic is forecasted to study the capacity of proposed elevated corridor and ramps. These details are given in following section.

Table 1.12 Diverted traffic based on O-D survey – Adugodi Junction

Vehicle Type	Actual Traffic	Diverted Traffic (Through)	% Diverted Traffic (Through)	Diverted Traffic (Ramp)	% Diverted (Ramp)
Car	7041	1776	25.2%	1278	18.1%
Minibus	193	47	24.1%	47	24.1%
Bus	336	149	44.4%	30	8.9%
Auto Rickshaw	3825	535	14.0%	157	4.1%
Two-Wheeler	19317	2902	15.0%	1908	9.9%
LCV	1099	98	8.9%	41	3.7%
2 Axle	2	0	0.0%	1	50.0%
3 Axle	3	1	33.3%	2	66.7%
Multi Axle	0	0	0.0%	0	0.0%

Table 1.13 Diverted traffic based on O-D survey – St John's Hospital Junction

Vehicle Type	Actual Traffic	Diverted Traffic (Through)	% Diverted Traffic (Through)	Diverted Traffic (Ramp)	% Diverted (Ramp)
Car	13403	6221	46.4%	3431	25.6%
Minibus	211	30	14.3%	0	0.0%
Bus	1026	202	19.7%	65	6.4%
Auto Rickshaw	6155	3245	52.7%	1612	26.2%
Two-Wheeler	30343	7972	52.5%	6013	39.6%
LCV	1961	267	13.6%	190	9.7%
2 Axle	14	5	37.5%	4	25.0%
3 Axle	14	1	7.7%	0	0.0%
Multi Axle	0	0	0.0%	0	0.0%

1.8 TRAFFIC ON PROPOSED GRADE SEPARATOR – ST. JOHN'S HOSPITAL

The traffic on proposed grade separators is derived from Turning Movement Counts carried out along existing road and percentage of diversion derived from Origin and

Destination surveys. The following **Table 1.14** represents the volume of traffic which can be diverted to proposed grade separator at St. John's Hospital junction. The peak hour traffic is used to calculate the diverted traffic.

Table 1.14 Traffic on Proposed Elevated Corridor

Vehicle Type	Through - 01			Ramp - 01			Through - 02		
	Existing	Grade Separator	At Grade	Existing	Grade Separator	At Grade	Existing	Grade Separator	At Grade
	Adugodi - Silk Board			Adugodi - Madiwala			Silk Board- Adugodi		
2 Wheeler	2351	1234	1117	370	147	223	2412	1266	1146
Auto Rickshaw	425	224	201	97	25	72	446	235	211
Car/ Jeep/ Van	853	396	457	258	66	192	994	461	533
Mini Bus	8	1	7	2	0	2	11	2	9
Std. Bus	150	30	120	0	0	0	93	18	75
LCV	143	19	124	34	3	31	128	17	111
2 Axle	0	0	0	1	0	1	1	0	1
3 Axle	4	0	4	0	0	0	0	0	0
MAV	0	0	0	0	0	0	0	0	0
Tractor with Trailer	2	0	2	0	0	0	2	0	2
Tractor without Trailer	3	0	3	1	0	1	1	0	1
Cycle	2	0	2	0	0	0	9	0	9
Cycle Rickshaw	0	0	0	0	0	0	0	0	0
Bullock Cart	0	0	0	0	0	0	0	0	0
Horse	0	0	0	0	0	0	0	0	0
Other (Special)	0	0	0	0	0	0	0	0	0

The traffic given in above tables are considered as base year traffic for elevated corridor which will be forecasted to 20 years by using growth rates given in below section. It is assumed that construction of proposed grade separator will be over in 2028 and opened for traffic movement in the year 2029.

1.9 TRAFFIC GROWTH RATES

The traffic growth rates can be established for each category of commercial vehicles as per IRC 108-2015 and IRC 37-2018. However, the traffic growth of 5% is used for the traffic forecast for this project as per clause 4.2.2 of IRC 37-2018 and are given in the following **Table 1.15.**

Table 1.15 Traffic Growth rates

Year	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	Multi Axle
2025	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2026	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2027	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2028	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2029	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2030	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2031	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2032	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2033	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2034	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2035	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2036	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2037	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2038	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2039	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2040	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2041	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2042	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2043	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2044	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2045	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2046	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2047	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%

Year	Car	Minibus	Bus	Auto Rickshaw	Two-Wheeler	LCV	2 Axle	3 Axle	Multi Axle
2048	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2049	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2050	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2051	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2052	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2053	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2054	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%
2055	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%

As per Clause B.2.1.4 of IRC 108-2015 normally, for a congested road (with high volume to capacity ratio) traffic growth is expected to be lower. So, in most cases, lower growth may be reasonable till the capacity augmentation is done. Even after capacity augmentation, traffic growth is unlikely to be uniform during the entire design period. The growth is expected to be higher in the initial periods after road widening/improvement and will become lower thereafter because of increasing traffic volume and reduced attractiveness of the road (i.e. more volume, less freedom of movement, more congestion, more travel time, etc.). Accordingly, separate sets of growth rates which are realistic for the context may be evolved for obtaining traffic volume forecast for different horizon years.

1.10 DESIGN TRAFFIC ESTIMATION

The traffic is forecasted for a period of 20 years. In the table, the year 2025 means the year from Jan 2025 to Dec 2025, i.e., Calendar year 2025. The construction period will be 3 years (2025-2028) and elevated corridor will be opened to traffic in the year 2029. The design service volume is calculated at 10th year and 20th year. Also, the design service volume is compared with forecasted traffic data to obtain the year in which V/C ratio exceeds 1. These are given in the summary table at the end. The following Table from **Table 1.16** and **Table 1.18** are for proposed the Grade separator at Shooley Junction.

Table 1.16 Projected Traffic – Shooley Junction (Without improvement) – At grade movement

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2025	7298	1274	1741	14	249	208	3	4	0	2	1	21	10815	9635
2026	7663	1338	1828	15	261	218	3	4	0	2	1	22	11356	10117
2027	8046	1405	1919	15	275	229	3	4	0	2	1	23	11924	10623
2028	**8448**	**1475**	**2015**	**16**	**288**	**241**	**3**	**5**	**0**	**2**	**1**	**24**	**12520**	**11154**
2029	8871	1549	2116	17	303	253	4	5	0	2	1	26	13146	11712
2030	9314	1626	2222	18	318	265	4	5	0	3	1	27	13803	12297
2031	9780	1707	2333	19	334	279	4	5	0	3	1	28	14493	12912
2032	10269	1793	2450	20	350	293	4	6	0	3	1	30	15218	13558
2033	10782	1882	2572	21	368	307	4	6	0	3	1	31	15979	14235
2034	11322	1976	2701	22	386	323	5	6	0	3	2	33	16778	14947
2035	11888	2075	2836	23	406	339	5	7	0	3	2	34	17616	15695
2036	12482	2179	2978	24	426	356	5	7	0	3	2	36	18497	16479
2037	13106	2288	3127	25	447	374	5	7	0	4	2	38	19422	17303
2038	**13761**	**2402**	**3283**	**26**	**470**	**392**	**6**	**8**	**0**	**4**	**2**	**40**	**20393**	**18168**
2039	14450	2522	3447	28	493	412	6	8	0	4	2	42	21413	19077
2040	15172	2649	3619	29	518	432	6	8	0	4	2	44	22484	20031
2041	15931	2781	3800	31	544	454	7	9	0	4	2	46	23608	21032
2042	16727	2920	3990	32	571	477	7	9	0	5	2	48	24788	22084
2043	17564	3066	4190	34	599	501	7	10	0	5	2	51	26028	23188
2044	18442	3219	4399	35	629	526	8	10	0	5	3	53	27329	24347
2045	19364	3380	4619	37	661	552	8	11	0	5	3	56	28695	25565
2046	20332	3549	4850	39	694	579	8	11	0	6	3	59	30130	26843
2047	21349	3727	5093	41	728	608	9	12	0	6	3	61	31637	28185
2048	**22416**	**3913**	**5348**	**43**	**765**	**639**	**9**	**12**	**0**	**6**	**3**	**65**	**33219**	**29594**

Table 1.17 Projected Traffic – Shooley Junction (With improvement) – At grade movement

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2025	5715	1153	1304	7	249	194	3	4	0	2	1	21	8652	7835
2026	6000	1210	1370	8	261	203	3	4	0	2	1	22	9085	8227
2027	6300	1271	1438	8	275	213	3	4	0	2	1	23	9539	8639

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2028	6615	1334	1510	8	288	224	3	5	0	2	1	24	10016	9071
2029	6946	1401	1586	9	303	235	4	5	0	2	1	26	10517	9524
2030	7293	1471	1665	9	318	247	4	5	0	3	1	27	11043	10000
2031	**7658**	**1545**	**1748**	**10**	**334**	**259**	**4**	**5**	**0**	**3**	**1**	**28**	**11595**	**10500**
2032	8041	1622	1835	10	350	272	4	6	0	3	1	30	12175	11025
2033	8443	1703	1927	11	368	286	4	6	0	3	1	31	12783	11577
2034	8865	1788	2024	11	386	300	5	6	0	3	2	33	13423	12155
2035	9309	1877	2125	12	406	315	5	7	0	3	2	34	14094	12763
2036	9774	1971	2231	12	426	331	5	7	0	3	2	36	14798	13401
2037	10263	2070	2343	13	447	348	5	7	0	4	2	38	15538	14071
2038	**10776**	**2173**	**2460**	**14**	**470**	**365**	**6**	**8**	**0**	**4**	**2**	**40**	**16315**	**14775**
2039	11315	2282	2583	14	493	383	6	8	0	4	2	42	17131	15514
2040	11880	2396	2712	15	518	402	6	8	0	4	2	44	17988	16289
2041	12474	2516	2847	16	544	422	7	9	0	4	2	46	18887	17104
2042	13098	2642	2990	17	571	444	7	9	0	5	2	48	19831	17959
2043	13753	2774	3139	17	599	466	7	10	0	5	2	51	20823	18857
2044	14441	2912	3296	18	629	489	8	10	0	5	3	53	21864	19800
2045	15163	3058	3461	19	661	513	8	11	0	5	3	56	22957	20790
2046	15921	3211	3634	20	694	539	8	11	0	6	3	59	24105	21829
2047	16717	3372	3816	21	728	566	9	12	0	6	3	61	25310	22921
2048	**17553**	**3540**	**4006**	**22**	**765**	**594**	**9**	**12**	**0**	**6**	**3**	**65**	**26576**	**24067**

Table 1.18 Projected Traffic – Shooley Junction (At Grade Separator)

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2025	1583	121	437	7	0	14	0	0	0	0	0	0	2163	1800
2026	1663	128	458	7	0	15	0	0	0	0	0	0	2271	1890
2027	1746	134	481	7	0	16	0	0	0	0	0	0	2384	1984
2028	1833	141	505	8	0	17	0	0	0	0	0	0	2504	2083
2029	1925	148	531	8	0	18	0	0	0	0	0	0	2629	2187
2030	2021	155	557	9	0	18	0	0	0	0	0	0	2760	2297
2031	2122	163	585	9	0	19	0	0	0	0	0	0	2898	2412
2032	2228	171	614	10	0	20	0	0	0	0	0	0	3043	2532
2033	2339	179	645	10	0	21	0	0	0	0	0	0	3195	2659
2034	2456	188	677	10	0	22	0	0	0	0	0	0	3355	2792

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2035	2579	198	711	11	0	24	0	0	0	0	0	0	3523	2931
2036	2708	208	747	12	0	25	0	0	0	0	0	0	3699	3078
2037	2844	218	784	12	0	26	0	0	0	0	0	0	3884	3232
2038	2986	229	823	13	0	27	0	0	0	0	0	0	4078	3393
2039	3135	240	864	13	0	29	0	0	0	0	0	0	4282	3563
2040	**3292**	**252**	**908**	**14**	**0**	**30**	**0**	**0**	**0**	**0**	**0**	**0**	**4496**	**3741**
2041	3456	265	953	15	0	32	0	0	0	0	0	0	4721	3928
2042	3629	278	1001	15	0	33	0	0	0	0	0	0	4957	4125
2043	3811	292	1051	16	0	35	0	0	0	0	0	0	5205	4331
2044	4001	307	1103	17	0	37	0	0	0	0	0	0	5465	4548
2045	4201	322	1158	18	0	38	0	0	0	0	0	0	5738	4775
2046	4411	338	1216	19	0	40	0	0	0	0	0	0	6025	5014
2047	4632	355	1277	20	0	42	0	0	0	0	0	0	6326	5264
2048	**4863**	**373**	**1341**	**21**	**0**	**45**	**0**	**0**	**0**	**0**	**0**	**0**	**6643**	**5528**

The following Table from **Table 1.19** and **Table 1.20** are for proposed the Grade separator at Adugodi Junction.

Table 1.19 Projected Traffic – Adugodi Junction (Without improvement) – At grade movement

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with	Tractor without	Cycle	Total Nos	Total PCU.
2025	5565	1069	1902	31	108	279	0	0	0	7	3	13	8977	8068
2026	5843	1122	1997	33	113	293	0	0	0	7	3	14	9426	8471
2027	6135	1179	2097	34	119	308	0	0	0	8	3	14	9897	8894
2028	6442	1238	2202	36	125	323	0	0	0	8	3	15	10392	9339
2029	6764	1299	2312	38	131	339	0	0	0	9	4	16	10912	9806
2030	7103	1364	2427	40	138	356	0	0	0	9	4	17	11457	**10296**
2031	7458	1433	2549	42	145	374	0	0	0	9	4	17	12030	10811
2032	7831	1504	2676	44	152	393	0	0	0	10	4	18	12632	11352
2033	8222	1579	2810	46	160	412	0	0	0	10	4	19	13263	11919
2034	8633	1658	2951	48	168	433	0	0	0	11	5	20	13926	12515
2035	9065	1741	3098	50	176	454	0	0	0	11	5	21	14623	13141
2036	9518	1828	3253	53	185	477	0	0	0	12	5	22	15354	13798
2037	9994	1920	3416	56	194	501	0	0	0	13	5	23	16121	14488

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with	Tractor without	Cycle	Total Nos	Total PCU.
2038	**10494**	**2016**	**3587**	**58**	**204**	**526**	**0**	**0**	**0**	**13**	**6**	**25**	**16927**	**15213**
2039	11018	2117	3766	61	214	552	0	0	0	14	6	26	17774	15973
2040	11569	2222	3954	64	225	580	0	0	0	15	6	27	18663	16772
2041	12148	2333	4152	68	236	609	0	0	0	15	7	28	19596	17610
2042	12755	2450	4359	71	248	639	0	0	0	16	7	30	20575	18491
2043	13393	2573	4577	75	260	671	0	0	0	17	7	31	21604	19416
2044	14062	2701	4806	78	273	705	0	0	0	18	8	33	22684	20386
2045	14766	2836	5047	82	287	740	0	0	0	19	8	34	23819	21406
2046	15504	2978	5299	86	301	777	0	0	0	20	8	36	25010	22476
2047	16279	3127	5564	91	316	816	0	0	0	20	9	38	26260	23600
2048	**17093**	**3283**	**5842**	**95**	**332**	**857**	**0**	**0**	**0**	**22**	**9**	**40**	**27573**	**24780**

Table 1.20 Projected Traffic – Adugodi Junction (With improvement) – At grade movement

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2025	4271	832	1415	25	69	258	0	0	0	7	3	13	6892	6200
2026	4484	874	1486	26	72	270	0	0	0	7	3	14	7236	6510
2027	4708	917	1560	28	76	284	0	0	0	8	3	14	7598	6836
2028	4944	963	1638	29	80	298	0	0	0	8	3	15	7978	7178
2029	5191	1011	1720	30	83	313	0	0	0	9	4	16	8377	7536
2030	5451	1062	1806	32	88	329	0	0	0	9	4	17	8796	7913
2031	5723	1115	1896	34	92	345	0	0	0	9	4	17	9236	8309
2032	6009	1171	1991	35	97	362	0	0	0	10	4	18	9697	8724
2033	6310	1229	2090	37	101	381	0	0	0	10	4	19	10182	9161
2034	6625	1291	2195	39	107	400	0	0	0	11	5	20	10691	9619
2035	**6957**	**1355**	**2305**	**41**	**112**	**420**	**0**	**0**	**0**	**11**	**5**	**21**	**11226**	**10100**
2036	7304	1423	2420	43	117	441	0	0	0	12	5	22	11787	10605
2037	7670	1494	2541	45	123	463	0	0	0	13	5	23	12377	11135
2038	8053	1569	2668	47	130	486	0	0	0	13	6	25	12995	11692
2039	8456	1647	2801	49	136	510	0	0	0	14	6	26	13645	12276
2040	8878	1730	2941	52	143	536	0	0	0	15	6	27	14327	12890
2041	9322	1816	3088	55	150	562	0	0	0	15	7	28	15044	13534
2042	9789	1907	3243	57	157	590	0	0	0	16	7	30	15796	14211
2043	10278	2002	3405	60	165	620	0	0	0	17	7	31	16586	14922

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2044	10792	2102	3575	63	174	651	0	0	0	18	8	33	17415	15668
2045	11331	2207	3754	66	182	683	0	0	0	19	8	34	18286	16451
2046	11898	2318	3942	70	191	718	0	0	0	20	8	36	19200	17274
2047	12493	2434	4139	73	201	754	0	0	0	20	9	38	20160	18137
2048	**13118**	**2555**	**4346**	**77**	**211**	**791**	**0**	**0**	**0**	**22**	**9**	**40**	**21168**	**19044**

The following Table from **Table 1.21** and **Table 1.25** are for proposed the Grade separator at St John's Hospital Junction.

Table 1.21 Projected Traffic – St John's Hospital Junction (Without improvement) – At grade movement

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2025	8575	1613	3410	50	274	426	7	5	0	6	6	18	14390	13112
2026	9004	1694	3581	53	288	447	7	5	0	6	6	19	15110	13768
2027	9454	1778	3760	55	302	470	8	6	0	7	7	20	15865	14456
2028	**9927**	**1867**	**3948**	**58**	**317**	**493**	**8**	**6**	**0**	**7**	**7**	**21**	**16658**	**15179**
2029	10423	1961	4145	61	333	518	9	6	0	7	7	22	17491	15938
2030	10944	2059	4352	64	350	544	9	6	0	8	8	23	18366	16735
2031	11491	2162	4570	67	367	571	9	7	0	8	8	24	19284	17571
2032	12066	2270	4798	70	386	599	10	7	0	8	8	25	20248	18450
2033	12669	2383	5038	74	405	629	10	7	0	9	9	27	21261	19372
2034	13303	2502	5290	78	425	661	11	8	0	9	9	28	22324	20341
2035	13968	2627	5555	81	446	694	11	8	0	10	10	29	23440	21358
2036	14666	2759	5832	86	469	729	12	9	0	10	10	31	24612	22426
2037	15399	2897	6124	90	492	765	13	9	0	11	11	32	25842	23547
2038	**16169**	**3042**	**6430**	**94**	**517**	**803**	**13**	**9**	**0**	**11**	**11**	**34**	**27134**	**24725**
2039	16978	3194	6752	99	543	843	14	10	0	12	12	36	28491	25961
2040	17827	3353	7089	104	570	886	15	10	0	12	12	37	29916	27259
2041	18718	3521	7444	109	598	930	15	11	0	13	13	39	31412	28622
2042	19654	3697	7816	115	628	976	16	11	0	14	14	41	32982	30053
2043	20637	3882	8207	120	659	1025	17	12	0	14	14	43	34631	31556
2044	21669	4076	8617	126	692	1076	18	13	0	15	15	45	36363	33133
2045	22752	4280	9048	133	727	1130	19	13	0	16	16	48	38181	34790
2046	23890	4494	9500	139	763	1187	20	14	0	17	17	50	40090	36530

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2047	25084	4718	9975	146	802	1246	20	15	0	18	18	53	42095	38356
2048	**26338**	**4954**	**10474**	**154**	**842**	**1308**	**22**	**15**	**0**	**18**	**18**	**55**	**44199**	**40274**

Table 1.22 Projected Traffic – St John's Hospital Junction (With improvement) – At grade movement

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Tractor with Trailer	Tractor without Trailer	Cycle	Total Nos	Total PCU.
2025	5928	1129	2487	47	226	386	6	5	0	6	6	18	10244	9455
2026	6224	1185	2611	50	237	405	7	5	0	6	6	19	10756	9928
2027	6536	1244	2742	52	249	425	7	5	0	7	7	20	11294	10424
2028	**6862**	**1306**	**2879**	**55**	**262**	**447**	**7**	**5**	**0**	**7**	**7**	**21**	**11858**	**10945**
2029	7205	1372	3023	57	275	469	8	6	0	7	7	22	12451	11493
2030	7566	1440	3174	60	289	492	8	6	0	8	8	23	13074	12067
2031	7944	1512	3333	63	303	517	9	6	0	8	8	24	13728	12671
2032	8341	1588	3499	67	318	543	9	7	0	8	8	25	14414	13304
2033	8758	1667	3674	70	334	570	9	7	0	9	9	27	15135	13969
2034	9196	1751	3858	73	351	599	10	7	0	9	9	28	15891	14668
2035	9656	1838	4051	77	368	629	10	8	0	10	10	29	16686	15401
2036	10139	1930	4254	81	387	660	11	8	0	10	10	31	17520	16171
2037	10646	2027	4466	85	406	693	11	8	0	11	11	32	18396	16980
2038	**11178**	**2128**	**4690**	**89**	**426**	**728**	**12**	**9**	**0**	**11**	**11**	**34**	**19316**	**17829**
2039	11737	2234	4924	94	448	764	13	9	0	12	12	36	20282	18720
2040	12324	2346	5170	98	470	802	13	10	0	12	12	37	21296	19656
2041	12940	2464	5429	103	494	842	14	10	0	13	13	39	22361	20639
2042	13587	2587	5700	108	518	884	15	11	0	14	14	41	23479	21671
2043	14266	2716	5985	114	544	929	15	11	0	14	14	43	24653	22755
2044	14980	2852	6284	119	571	975	16	12	0	15	15	45	25885	23892
2045	15728	2994	6599	125	600	1024	17	12	0	16	16	48	27180	25087
2046	16515	3144	6929	132	630	1075	18	13	0	17	17	50	28539	26341
2047	17341	3301	7275	138	661	1129	19	14	0	18	18	53	29966	27658
2048	**18208**	**3466**	**7639**	**145**	**695**	**1185**	**20**	**14**	**0**	**18**	**18**	**55**	**31464**	**29041**

Table 1.23 Projected Traffic – St John's Hospital Junction (Adugodi to Madiwala) – Exit Ramp

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Total Nos	Total PCU.
2025	147	25	66	0	0	3	0	0	0	242	212
2026	154	27	69	0	0	3	0	0	0	254	222
2027	162	28	73	0	0	4	0	0	0	266	233
2028	**170**	**29**	**76**	**0**	**0**	**4**	**0**	**0**	**0**	**280**	**245**
2029	178	31	80	0	0	4	0	0	0	294	257
2030	187	32	84	0	0	4	0	0	0	308	270
2031	196	34	89	0	0	4	0	0	0	324	284
2032	206	36	93	0	0	5	0	0	0	340	298
2033	216	38	98	0	0	5	0	0	0	357	313
2034	227	39	102	0	0	5	0	0	0	375	328
2035	239	41	108	0	0	5	0	0	0	393	345
2036	251	43	113	0	0	6	0	0	0	413	362
2037	263	46	119	0	0	6	0	0	0	434	380
2038	**276**	**48**	**125**	**0**	**0**	**6**	**0**	**0**	**0**	**455**	**399**
2039	290	50	131	0	0	7	0	0	0	478	419
2040	305	53	137	0	0	7	1	0	0	502	440
2041	320	55	144	0	0	7	1	0	0	527	462
2042	336	58	151	0	0	8	1	0	0	554	485
2043	353	61	159	0	0	8	1	0	0	581	509
2044	370	64	167	0	0	8	1	0	0	610	535
2045	389	67	175	0	0	9	1	0	0	641	561
2046	408	71	184	0	0	9	1	0	0	673	590
2047	429	74	193	0	0	10	1	0	0	707	619
2048	**450**	**78**	**203**	**0**	**0**	**10**	**1**	**0**	**0**	**742**	**650**

Table 1.24 Projected Traffic – St John's Hospital Junction (Adugodi to Silk Board) – Through traffic on grade separator

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Total Nos	Total PCU.
2025	1234	224	396	1	30	19	0	0	0	1904	1685
2026	1296	235	416	1	31	20	0	0	0	2000	1769
2027	1361	247	436	1	33	21	0	0	0	2100	1857
2028	**1429**	**259**	**458**	**1**	**34**	**23**	**0**	**0**	**0**	**2205**	**1950**

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Total Nos	Total PCU.
2029	1500	272	481	1	36	24	0	0	0	2315	2048
2030	1575	286	505	1	38	25	0	0	0	2431	2150
2031	1654	300	530	2	40	26	0	0	0	2552	2258
2032	1737	315	557	2	42	27	0	0	0	2680	2371
2033	1824	331	585	2	44	29	0	0	0	2814	2489
2034	1915	347	614	2	46	30	0	0	0	2954	2614
2035	2011	365	645	2	48	32	0	1	0	3102	2744
2036	2111	383	677	2	51	33	0	1	0	3257	2882
2037	2217	402	711	2	53	35	0	1	0	3420	3026
2038	**2327**	**422**	**746**	**2**	**56**	**37**	**0**	**1**	**0**	**3591**	**3177**
2039	2444	443	784	2	59	39	0	1	0	3771	3336
2040	2566	466	823	2	61	40	0	1	0	3959	3503
2041	2694	489	864	2	65	42	0	1	0	4157	3678
2042	2829	513	907	3	68	45	0	1	0	4365	3862
2043	2970	539	953	3	71	47	0	1	0	4583	4055
2044	3119	566	1000	3	75	49	0	1	0	4813	4257
2045	3275	594	1050	3	78	52	0	1	0	5053	4470
2046	3439	624	1103	3	82	54	0	1	0	5306	4694
2047	3611	655	1158	3	86	57	0	1	0	5571	4928
2048	**3791**	**688**	**1216**	**4**	**91**	**60**	**0**	**1**	**0**	**5850**	**5175**

Table 1.25 Projected Traffic – St John's Hospital Junction (Silk Board to Adugodi) – Through traffic on grade separator

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Total Nos	Total PCU.
2025	1266	235	461	2	18	17	0	0	0	2000	1761
2026	1330	247	484	2	19	18	0	0	0	2100	1849
2027	1396	259	508	2	20	19	0	0	0	2205	1941
2028	**1466**	**272**	**534**	**2**	**21**	**20**	**0**	**0**	**0**	**2316**	**2038**
2029	1539	286	561	2	22	21	0	0	0	2431	2140
2030	1616	300	589	2	23	22	0	0	0	2553	2247
2031	1697	315	618	2	25	23	1	0	0	2681	2360
2032	1782	331	649	2	26	24	1	0	0	2815	2477
2033	1871	347	681	2	27	26	1	0	0	2955	2601
2034	1964	365	715	2	28	27	1	0	0	3103	2731
2035	2063	383	751	3	30	28	1	0	0	3258	2868

Year	2 Wheeler	Auto Rickshaw	Car/ Jeep/ Van	Mini Bus	Std. Bus	LCV	2 Axle	3 Axle	MAV	Total Nos	Total PCU.
2036	2166	402	789	3	31	30	1	0	0	3421	3011
2037	2274	422	828	3	33	31	1	0	0	3592	3162
2038	**2388**	**443**	**870**	**3**	**35**	**33**	**1**	**0**	**0**	**3772**	**3320**
2039	2507	465	913	3	36	34	1	0	0	3960	3486
2040	2633	489	959	3	38	36	1	0	0	4158	3660
2041	2764	513	1007	3	40	38	1	0	0	4366	3843
2042	2902	539	1057	4	42	40	1	0	0	4585	4036
2043	3048	566	1110	4	44	42	1	0	0	4814	4237
2044	3200	594	1165	4	46	44	1	0	0	5054	4449
2045	3360	624	1224	4	49	46	1	0	0	5307	4672
2046	3528	655	1285	4	51	48	1	0	0	5573	4905
2047	3704	688	1349	5	54	51	1	0	0	5851	5150
2048	**3889**	**722**	**1417**	**5**	**56**	**53**	**1**	**0**	**0**	**6144**	**5408**

The importance of these proposed grade separators will be to reduce traffic congestion on existing Hosur Road and increase V/C Ratio of existing roads (at grade movement). The impact of proposed elevated corridor onto existing at grade Hosur Road will be studied in below section. The reduction in terms of Nos. and PCUs at each junction are given in following **Table 1.26** for existing junctions.

Table 1.26 Comparison between without improvement and with improvement (Elevated Corridor) for existing junctions

Vehicle Type	Shooley Junction		Adugodi Junction		St John's Hospital Junction	
	Total (No Improvement)	Total (With Improvement)	Total (No Improvement)	Total (With Improvement)	Total (No Improvement)	Total (With Improvement)
2-Wheeler	7298	5715	5565	4271	8575	5928
Auto Rickshaw	1274	1153	1069	832	1613	1129
Car/ Jeep/ Van	1741	1304	1902	1415	3410	2487
Minibus	14	7	31	25	50	47
Std. Bus	249	249	108	69	274	226
LCV	208	194	279	258	426	386
2 Axle	3	3	0	0	7	6
3 Axle	4	4	0	0	5	5
MAV	0	0	0	0	0	0
Tractor with Trailer	2	2	7	7	6	6

Vehicle Type	Shooley Junction		Adugodi Junction		St John's Hospital Junction	
	Total (No Improvement)	Total (With Improvement)	Total (No Improvement)	Total (With Improvement)	Total (No Improvement)	Total (With Improvement)
Tractor without Trailer	1	1	3	3	6	6
Cycle	21	21	13	13	18	18
Cycle Rickshaw	0	0	0	0	0	0
Bullock Cart	0	0	0	0	0	0
Horse	0	0	0	0	0	0
Other (Special)	0	0	0	0	0	0

Table 1.27 Traffic Forecast at existing junctions without improvement and with improvement

Junction	Shooley Junction				Adugodi Junction				St John's Hospital Junction			
Year	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.
	No Improvement		With Improvement		No Improvement		With Improvement		No Improvement		With Improvement	
2025	10815	9635	8652	7835	8977	8068	6892	6200	**14390**	**13112**	10244	9455
2026	**11356**	**10117**	9085	8227	9426	8471	7236	6510	15110	13768	10756	9928
2027	11924	10623	9539	8639	9897	8894	7598	6836	15865	14456	**11294**	**10424**
2028	12520	11154	10016	9071	10392	9339	7978	7178	16658	15179	11858	10945
2029	13146	11712	10517	9524	10912	9806	8377	7536	17491	15938	12451	11493
2030	13803	12297	**11043**	**10000**	**11457**	**10296**	8796	7913	18366	16735	13074	12067
2031	14493	12912	11595	10500	12030	10811	9236	8309	19284	17571	13728	12671
2032	15218	13558	12175	11025	12632	11352	9697	8724	20248	18450	14414	13304
2033	15979	14235	12783	11577	13263	11919	10182	9161	21261	19372	15135	13969
2034	16778	14947	13423	12155	13926	12515	10691	9619	22324	20341	15891	14668
2035	17616	15695	14094	12763	14623	13141	**11226**	**10100**	23440	21358	16686	15401
2036	18497	16479	14798	13401	15354	13798	11787	10605	24612	22426	17520	16171
2037	19422	17303	15538	14071	16121	14488	12377	11135	25842	23547	18396	16980
2038	20393	18168	16315	14775	16927	15213	12995	11692	27134	24725	19316	17829
2039	21413	19077	17131	15514	17774	15973	13645	12276	28491	25961	20282	18720
2040	22484	20031	17988	16289	18663	16772	14327	12890	29916	27259	21296	19656
2041	23608	21032	18887	17104	19596	17610	15044	13534	31412	28622	22361	20639
2042	24788	22084	19831	17959	20575	18491	15796	14211	32982	30053	23479	21671
2043	26028	23188	20823	18857	21604	19416	16586	14922	34631	31556	24653	22755
2044	27329	24347	21864	19800	22684	20386	17415	15668	36363	33133	25885	23892
2045	28695	25565	22957	20790	23819	21406	18286	16451	38181	34790	27180	25087
2046	30130	26843	24105	21829	25010	22476	19200	17274	40090	36530	28539	26341

Junction	Shooley Junction				Adugodi Junction				St John's Hospital Junction			
Year	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.	Total Nos	Total PCU.
	No Improvement		With Improvement		No Improvement		With Improvement		No Improvement		With Improvement	
2047	31637	28185	25310	22921	26260	23600	20160	18137	42095	38356	29966	27658
2048	33219	29594	26576	24067	27573	24780	21168	19044	44199	40274	31464	29041

Shooley Junction: The present peak hour capacity of the junction is **9635 PCUs per Hour**. The junction without any improvement warrants for grade separator as per clause 5.10.4 of IRC SP 92-2010 in year **2026**. The junction with improvement (elevated corridor) warrants for grade separator as per clause 5.10.4 of IRC SP 92-2010 in year **2030**.

Adugodi Junction: The present peak hour capacity of the junction is **8068 PCUs per Hour**. The junction without any improvement warrants for grade separator as per clause 5.10.4 of IRC SP 92-2010 in year **2030**. The junction with improvement (elevated corridor) warrants for grade separator as per clause 5.10.4 of IRC SP 92-2010 in year **2035**.

St John's Hospital Junction: The present peak hour capacity of the junction is **13112 PCUs per Hour** which already exceeds design capacity. The junction without any improvement warrants for grade separator as per clause 5.10.4 of IRC SP 92-2010 in year **2025**. The junction with improvement (elevated corridor) warrants for grade separator as per clause 5.10.4 of IRC SP 92-2010 in year **2027.**

1.11 CAPACITY ANALYSIS

The design service volume of city roads is analysed as per Table 2 given in IRC 92-2017 "Guidelines for the design of Interchanges in Urban Areas". The design service volumes are given in the following **Table 1.28**.

Table 1.28 Base Capacity and Recommended Design Service Volume of Urban Road Sections

Sl No	Type of Carriageway	Capacity	Lane Capacity (PCU/h/lane)
1	Two-Lane Undivided (7.0 m)	2400	1200
2	Four-Lane Undivided (14.0 m)	5000	1250
3	Four-Lane Divided (7.5 m)	5400 (27000	1350
4	Six-Lane Divided (11.0 m)	8400 (4200)	1400
5	Eight-Lane Divided (14.0 m)	13600 (6800)	1700
6	Eight-Lane Divided Expressway (14.0 m)	9200	2300
7	Ten-Lane Divided Urban Road (17.5 m)	10000	2000

Note: The values in parenthesis/brackets represent PCUs per hour per direction.

The forecasted traffic given in **Table 1.16** to **Table 1.27** in terms of through traffic and traffic for ramps are compared with design service volume given in **Table 1.28** above and details are given in following paragraph.

Table 1.29 Forecasted Traffic and V/C Ratio Calculation with remarks for Through Traffic

SL No	Description	Traffic Volume				C.W. Width	Capacity	V/C Ratio			Remarks
		Traffic 2025	Traffic 2028	Traffic 2038	Traffic 2048			2028	2038	2048	
Shooley Junction Grade Separator											
1	Through (Brigade Road-Silk Board)	848	982	1600	2606	11.5	3600	0.579	0.943	1.536	V/C>1 in 2039
2	Through-(Silk Board-Brigade Road)	951	1101	1794	2922						
St. John's Hospital Junction Grade Separator											
3	Through-1 (Adugodi-Silk Board)	1685	1950	3177	5175	7.5	2700	0.722	1.177	1.917	V/C>1 in 2035
4	Ramp-1 (Adugodi-Madiwala)	212	245	399	650	7.5	2700	0.091	0.148	0.241	V/C<1
5	Through-2 (Silk Board-Adugodi)	1761	2038	3320	5408	7.5	2700	0.755	1.230	2.003	V/C>1 in 2034
Adugodi Junction Grade Separator approach											
6	Through-1 + Ramp-1	1897	2195	3576	5825	7.5	2700	0.813	1.324	2.157	V/C>1 in 2032
7	Through-2	1761	2038	3320	5408	7.5	2700	0.755	1.230	2.003	V/C>1 in 2034

1.12 CONCLUSION

The turning movement results obtained for all junctions on Hosur road show that the capacity of most of the junctions already exceeded the design capacity of junction (10000 PCUs per Hour) which requires immediate intervention to avoid bottlenecks or congestion at the junctions. This can be done either by making changes to policy (modal shifts and promoting use of public transport) or by construction of grade separators at each junction. Also, there are other junctions along the corridor, mainly, Anepalya road junction, Koramangala and Forum road junctions. There are totally 5 junctions within 4.2 Km stretch and stand alone fly overs at all junctions will create roller coaster effect for the road users. Also, few junctions are closely spaced, requiring combining of junctions, Hence, it requires elevated road along the corridor, segregating through traffic, so that conflicts along these junctions are minimized.

APPENDIX - 2 – GEOTECH REPORT

ISO No.	QMP 8.2.4 R/A
Report No.	GECPL/270126-722/R

GEOTECHNICAL INVESTIGATION REPORT FOR THE PROPOSED CONSTRUCTION OF ELEVATED CORRIDORS FROM SHOLAY CIRCLE TO ST. JOHN HOSPITAL ROAD ON HOSUR ROAD VIA ANEPALYA JUNCTION AND ADUGODI JUNCTION IN BENGALURU CENTRAL AND SOUTH CITY CORPORATION LIMITS

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Report on	:	Geotechnical investigation for the Proposed Construction of Elevated Corridors from sholay Circle to St.John Hospital Road on Hosur Road via Anepalya Junction and Adugodi Junction in Bengaluru Central and South City Corporation limits
Report No	:	GECPL/270126-722/R
Report for	:	M/s. Bengaluru Smart Infrastructure Limited No: 108, 1st Floor, Annex-2 Building NR Square, Bangalore – 560 002
Reference	:	E-mail Confirmation
Managing Director	:	Dr. Jayaprakash K N
Technical Advisor & Report by	:	Mr. Nagesh C Technical Manager (Geo-Technical Engg)
Field investigation carried out by	:	Mr. Bharath Das & Team, Site Engineer

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LIST OF ANNEXURES

List of Annexure	Description
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Annexure II -	Field Records and Bore Logs
Annexure III -	Laboratory Test Results
Annexure IV -	Typical Sieve Curves

1.0 INTRODUCTION

M/s. Bengaluru Smart Infrastructure Limited, Bengaluru had entrusted us to carry Geotechnical investigation for the proposed Construction of Elevated Corridors from sholay Circle to St. John Hospital Road on Hosur Road via Anepalya Junction and Adugodi Junction in Bengaluru Central and South City Corporation limits. The primary objective of this investigation is to establish the geotechnical condition at the site and to evaluate the allowable bearing pressure and other engineering design parameters through the various field and laboratory tests. This report consists of the details about the field and laboratory tests performed and the recommendations made based on the test results.

2.0 SCOPE

Field work comprising of drilling of seven boreholes conducting SPT tests, collection of samples started on 27.01.2026 and was completed on 29.01.2026. The primary objective of this investigation was to obtain information about the sub-surface conditions at the site and obtain net allowable bearing pressure for design of foundations. Fig A: shows the location of boreholes for the proposed construction site ***(Refer Annexure I)***. Details are summarized below:

BH No.	Reference Location	Depth of explorations (m)	Water Table, m
BH-1	Koramangala	15.0	Nil
BH-2	MG Road	15.0	Nil
BH-3	Audugodi	15.0	Nil
BH-1	Audugodi to Sarjapura Road (Old)	11.2	Nil
BH-2		20.0	Nil
BH-3		21.0	Nil
BH-4		21.0	Nil

3.0 FIELD INVESTIGATION- RELEVANT DESCRIPTION

3.1 Boring and Drilling

The field investigation comprised of advancing 150mm boreholes using rotary drilling rig with bentonite mud circulation. Standard penetration test (SPT) was conducted at every 1.50m intervals as per IS: 2131. The number of blows for 30cm penetration of split spoon sampler was recorded as N-values. The boreholes were terminated after drilling to their respective depth. The various sub-surface strata are presented in the respective bore charts.

3.2 Standard Penetration Test (SPT) in boreholes

Standard Penetration Test (SPT) to determine penetration resistance was conducted in the boreholes using the procedure described in IS: 2131. In this method, driving bit is replaced by split spoon sampler (50.8 mm OD and 35 mm ID) and the sampler is driven by dropping 63.5 kg hammer on the top of the driving collar with a free fall of 75 cm. The length of the sampler is 60 cm. The sampler is first driven through 15 cm as "Seating Drive". It is further driven through 30 cm. The number of blows required to drive the sampler for 30 cm beyond seating drive is termed as "Penetration Resistance, N". Representative samples were collected using split spoon sampler. Where full 30cm penetration beyond seating drive was not possible, number of blows and corresponding penetration is mentioned in bore logs. ***Refer Annexure II for Bore logs.***

3.3 Sampling in boreholes

In view of sandy Silt , representative samples were mainly collected from split spoon sampler used for conducting SPT at close intervals of 1.5m up to end of respective strata. Rock formations are usually drilled by tungsten carbide core bits, representative core samples are retained and collected by core barrel.

3.4 Ground water table

At time of investigations, subsequent to completion of borehole and after allowing water level to stabilize for minimum 24 hours, water table was not encountered at any depth below natural ground level during the time of investigation; however, a point to be noted is that, water levels are invariably subjected to seasonal fluctuations.

4.0 LABORATORY TESTS ON SAMPLES

Assessment of Geotechnical Properties - Samples from Boreholes

The following Tests were carried out

- Grain size analysis
- Natural Moisture content
- Atterberg's Limits

Test results are as shown in Annexure III

5.0 SUB - SOIL PROFILE ANALYSIS

5.1 Nature of Soil Stratification

Based on detailed analysis, the soil conditions described is summarized for the entire project site as under

Layer I: Soil Overburden

The sub-soil stratification essentially comprises of sandy Silt/ silty formations with layer thickness of 6.0m to 10.5m.

Layer II: Completely weathered rock (Soft Disintegrated rock)

Occurs below layer I and comprises of 'very dense' complete to highly weathered rock (SPT 'N' values consistently N >100 and Nil core recovery). In 'in-situ' conditions, stratum is considered 'very dense/stiff' /incompressible with very good bearing characteristics. In this layer sample recovery was limited and sufficient for visual classification only.

Layer III- Rock formations

This layer occurs below layer II. Based on the core recovery and rock Quality Designation rock may classified as Soft Rock formations given below.

5.2 Sub-Soil stratification Description:

BH No.	Reference	Explored Depth, m	Thickness of layer in sequence (m)			
			Layer – I	Layer – II	Layer -III	
			Soil/CWR (N<100)	CWR(N>100)	Rock Formations	Remarks
BH-1	Koramangala	15.0	0.0 to 10.5	10.5 to 15.0	--	--
BH-2	MG Road	15.0	0.0 to 7.5	7.5 to 15.0	--	--
BH-3	Audugodi	15.0	0.0 to 6.0	6.0 to 15.0	--	--

BH No.	Reference	Explored Depth, m	Thickness of layer in sequence (m)			
			Layer – I	Layer – II	Layer -III	
			Soil/CWR (N<100)	CWR(N>100)	Rock Formations	Remarks
BH-1	Audugodi to Srajapura Road (Old)	11.2	0.0 to 4.5	4.5 to 8.2	8.2 to 11.2	HR
BH-2		20.0	0.0 to 13.5	13.5 to 17.5	17.5 to 20.0	SR/MWR
BH-3		21.0	0.0 to 21.0	--	--	--
BH-4		21.0	0.0 to 13.5	13.5 to 21.0	--	--

SR- Soft Rock, MWR- Moderately weathered rock, CWR-Completely Weathered Rock, HR-Hard Rock

6.0 RECOMMENDATIONS FOR DESIGN OF FOUNDATIONS

6.1 RECOMMENDATIONS FOR DEEP FOUNDATIONS

6.1.1 Inferences drawn from borehole investigations

Heavy load transfer is anticipated from the Bridge structure envisaged. Hence deep foundations such as Bored Cast-in-situ Piles may be recommended. Pile diameter has been considered as 1.0m and 1.2m. Piles should be socketed 3 **times the Pile diameter in dense weathered rock /refusal strata (N>100) or one times the pile diameter in to hard rock whichever is met earlier**.

Reference	Pile diameter, D (m)	*Depth of pile, m	Safe axial load (tons)	Uplift Capacity, Tons	Lateral load (tons) (fixed head condition)	Depth of fixity, m
I	II	III	IV	V	VI	VII
BH – 1 (Koramangala)	1.0	14.0	350	75	40	8.0
	1.1		400	95	50	8.5
	1.2		450	120	60	9.0
BH – 2 (MG Road)	1.0	13.0	350	75	40	8.0
	1.1		400	95	50	8.5
	1.2		450	120	60	9.0
BH – 3 (Audugodi)	1.0	13.0	350	75	40	8.0
	1.1		400	95	50	8.5
	1.2		450	120	60	9.0

Reference	Pile diameter, D (m)	*Depth of pile, m	Safe axial load (tons)	Uplift Capacity, Tons	Lateral load (tons) (fixed head condition)	Depth of fixity, m
BH-1 (Old)	1.0	9.0	350	75	40	8.0
	1.1		400	95	50	8.5
	1.2		450	120	60	9.0
BH-2 (Old)	1.0	17.5	350	75	40	8.0
	1.1		400	95	50	8.5
	1.2		450	120	60	9.0
BH-3 (Old)	1.0	Hard Strata was encountered up to termination depth	350	75	40	8.0
	1.1		400	95	50	8.5
	1.2		450	120	60	9.0
BH-4 (Old)	1.0	18.0	350	75	40	8.0
	1.1		400	95	50	8.5
	1.2		450	120	60	9.0

However actual load carrying capacity of pile may be arrived through initial pile load test

CONCLUDING REMARKS

This Geotechnical report is valid for site conditions that prevailed at time of subsurface explorations. Geo-technical design recommendations are based on the data derived from borehole investigations. There is a possibility that strata variations could occur. If any variations indicate significant deviations from the findings of this report, same shall be brought to the notice of Geo-technical consultant for appropriate design review.

For GEOENGINEERING COMPANY PRIVATE LTD

(Dr. JAYAPRAKASH K N)

Annexure I

Fig A: Location of Boreholes

ANNEXURE II

Client	M/s. Bengaluru Smart Infrastructure Limited	**BOREHOLE - 01**	**Size of Borehole**	150mm
Job No	722		**Ground Water Table**	Nil
Project	Construction of elevated Corridor		**Commenced**	29-01-26
Location	Koramanagala		**Completed**	29-01-26

Description of Sub-soil stratum	**Depth (m)**	**Legend**	**Sample**	**SPT TEST, number of blows recorded**			**N Value = N_2+N_3**	**Core Recovery, %**	**RQD, %**	**Remarks**
				1st 15cm	**2nd15cm**	**3rd15cm**				
				N_1	**N_2**	**N_3**				
Filled up	0.5									
	1.5									
Pinkish brown sandy Silt	3.0		SPT	10	15	18	33			
	4.5		SPT	12	19	24	43			
	6.0		SPT	18	24	28	52			**Refusal Strata**
	7.5		SPT	19	25	33	58			
	9.0		SPT	20	28	35	63			
Brownish white CWR	10.5		SPT	35	50B/15cm	R	>100			
	12.0		WS	50B/10cm	R		>100			No Core Recovary, Only Wash Sample collected
	13.5		WS	R			>100			
	15.0		WS	R			>100			

SPT=Standard Penetration test	Refusal means SPT N>50	B= No. of blows	R=Rebound	SR: Soft Rock
HR:Hard Rock	DS=Disturbed Sample	CWR: completely weathered rock	SDR: Soft Disintegrated Rock	

Bore hole was terminated at 15.0m depth below existing ground level

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Client	M/s. Bengaluru Smart Infrastructure Limited	**BOREHOLE - 02**	**Size of Borehole** 150mm
Job No	722		**Ground Water Table** Nil
Project	Construction of elevated Corridor		**Commenced** 27-01-26
Location	MG Road Metro Station		**Completed** 27-01-26

Description of Sub-soil stratum	Depth (m)	Legend	Sample	SPT TEST, number of blows recorded			N Value = N_2+N_3	Core Recovery, %	RQD, %	Remarks
				1st 15cm	2nd15cm	3rd15cm				
				N_1	N_2	N_3				
Filled up	0.5									
	1.5									
Brownish white sandy Silt	3.0		SPT	10	12	14	26			
	4.5		SPT	13	15	17	32			
Grayish white sandy Silt	6.0		SPT	15	18	22	40			
Grayish white CWR	7.5		SPT	35	50B/5cm	R	>100			**Refusal Strata**
Brownish white CWR	9.0		SPT	50B/2cm	R		>100			
	10.5		WS	25B/0cm	R		>100			
	12.0		WS	R			>100			No Core Recovary, Only Wash Sample collected
	13.5		WS	R			>100			
	15.0		WS	R			>100			

SPT=Standard Penetration test	Refusal means SPT N>50	B= No. of blows	R=Rebound	SR: Soft Rock
HR:Hard Rock	DS=Disturbed Sample	CWR: completely weathered rock	SDR: Soft Disintegrated Rock	

Bore hole was terminated at 15.0m depth below existing ground level

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Client	M/s. Bengaluru Smart Infrastructure Limited	**BOREHOLE - 03**	**Size of Borehole** 150mm
Job No	722		**Ground Water Table** Nil
Project	Construction of elevated Corridor		**Commenced** 28-01-26
Location	Audugodi		**Completed** 28-01-26

Description of Sub-soil stratum	Depth (m)	Legend	Sample	SPT TEST, number of blows recorded			N Value = N_2+N_3	Core Recovery, %	RQD, %	Remarks
				1st 15cm	2nd 15cm	3rd 15cm				
				N_1	N_2	N_3				
Filled up	0.5									
	1.5									
Reddish sandy Silt	3.0		SPT	8	10	12	22			
	4.5		SPT	12	14	16	30			
Grayish white CWR	6.0		SPT	35	50B/6cm	R	>100			**Refusal Strata**
Brownish white CWR	7.5		SPT	50B/3cm	R		>100			
	9.0		SPT	50B/4cm	R		>100			
	10.5		WS	25B/0cm	R		>100			
	12.0		WS	R			>100			No Core Recovary, Only Wash Sample collected
	13.5		WS	R			>100			
	15.0		WS	R			>100			

SPT=Standard Penetration test	Refusal means SPT N>50	B= No. of blows	R=Rebound	SR: Soft Rock
HR:Hard Rock	DS=Disturbed Sample	CWR: completely weathered rock	SDR: Soft Disintegrated Rock	

Bore hole was terminated at 15.0m depth below existing ground level

Client	M/s. BBMP	**BOREHOLE - 01(Old)**	**Size of Borehole** 150mm
Job No	300		**Ground Water Table** Nil
Project	ROB		**Commenced** 04.06.19
Location	Adugodi to Sarjapur Road Junction		**Completed** 05.06.19

Description of Sub-soil stratum	**Depth (m)**	**Legend**	**Sample**	**SPT TEST, number of blows recorded**			**N Value = N_2+N_3**	**Core Recovery, %**	**RQD, %**	**Remarks**
				1st 15cm	**2nd15cm**	**3rd15cm**				
				N_1	**N_2**	**N_3**				
Filled up	0.0									
	0.5		DS							
Brownish yellow sandy Silt	1.5		SPT DS	2	3	3	6			
	3.0		SPT DS	4	5	7	12			
Brownish grey sandy Silt	4.5		SPT DS	6	8	15	23			
Brownish grey sandy Silt with gravels	6.0		SPT	50B/2cm	R		>100			***Refusal Strata***
Brownish grey CWR	7.5		SPT DS	50B/2cm	R		>100			
	8.2									
Brownish grey SR - MWR	8.7		CR					92	66	
Whitish grey Hard Rock	9.7		CR					98	98	
	11.2		CR					99	94	

SPT=Standard Penetration test	Refusal means SPT N>50	B= No. of blows	R=Rebound	SR: Soft Rock
HR:Hard Rock	DS=Disturbed Sample	CWR: completely weathered rock	MWR: Moderately weathered rock	

Bore hole was terminated at 11.2m depth below existing ground level

GEO ENGINEERING COMPANY PVT. LTD., BANGALORE
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Client	M/s. BBMP	**BOREHOLE - 02(Old)**	**Size of Borehole** 150mm
Job No	300		**Ground Water Table** Nil
Project	ROB		**Commenced** 08.06.19
Location	Adugodi to Sarjapur Road Junction		**Completed** 09.06.19

Description of Sub-soil stratum	Depth (m)	Legend	Sample	SPT TEST, number of blows recorded			N Value = N_2+N_3	Core Recovery, %	RQD, %	Remarks
				1st 15cm	2nd 15cm	3rd 15cm				
				N_1	N_2	N_3				
Filled up	0.0									
	0.5		DS							
Grayish yellow sandy Silt with gravels	1.5		SPT DS	8	11	14	25			
	3.0		SPT DS	11	17	14	31			
Yellowish grey sandy Silt with gravels	4.5		SPT DS	13	14	16	30			
	6.0		SPT DS	13	14	15	29			
	7.5		SPT DS	14	15	15	30			
Brownish grey sandy Silt with gravels	9.0		SPT DS	14	16	18	34			
	10.5		SPT DS	20	30	28	58			
Yellowish grey sandy Silt with gravels	12.0		SPT DS	13	14	16	30			
	13.5		SPT DS	20	21	22	43			
Whitish grey CWR	15.0		SPT DS	50B/5cm	R		>100			***Refusal Strata***
	16.5		SPT DS	50B/2cm	R		>100			
Whitish grey SR - MWR	17.5		DS							
	19.0		CR					33	30	
	20.0		CR					46	46	

SPT=Standard Penetration test	Refusal means SPT N>50	B= No. of blows	R=Rebound	SR: Soft Rock
HR:Hard Rock	DS=Disturbed Sample	CWR: completely weathered rock	MWR: Moderately weathered rock	

Bore hole was terminated at 20.0m depth below existing ground level

GEO ENGINEERING COMPANY PVT. LTD., BANGALORE
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Client	M/s. BBMP	**BOREHOLE - 03(Old)**		**Size of Borehole**	150mm
Job No	300			**Ground Water Table**	Nil
Project	ROB			**Commenced**	08.06.19
Location	Adugodi to Sarjapur Road Junction			**Completed**	09.06.19

Description of Sub-soil stratum	**Depth (m)**	**Legend**	**Sample**	**SPT TEST, number of blows recorded**			**N Value = N_2+N_3**	**Core Recovery, %**	**RQD, %**	**Remarks**
				1st 15cm	**2nd15cm**	**3rd15cm**				
				N_1	**N_2**	**N_3**				
Reddish sandy Silt	0.0									
	0.5		DS							
Yellowish brown silty Sand	1.5		SPT	5	8	11	19			
	3.0		DS							
Whitish to pinkish brown sandy Silt	4.5		SPT	9	12	16	28			
			DS							
Whitish to brownish yellow sandy Silt	6.0		SPT	12	20	25	45			
			DS							
Grayish to yellowish brown sandy Silt	7.5		SPT	10	17	22	39			
	9.0		DS	10	18	29	47			
Whitish to pinkish brown sandy Silt	10.5		SPT	14	19	29	48			
			DS							
Pinkish to grayish white sandy Silt	12.0		SPT	13	19	24	43			
			DS							
Pinkish to whitish brown sandy Silt	13.5		SPT	18	23	29	52			
	15.0		DS	15	20	27	47			
Whitish yellow sandy gravels	16.5		SPT	15	25	36	61			***Refusal Strata***
			DS							
Pinkish to brownsih grey sandy Silt	18.0		SPT	18	22	40	62			
			DS							
Pinkish to brownsih white sandy Silt	19.5		SPT	20	25	30	55			
			DS							
Whitish grey sandy Silt	21.0		CR	26	30	33	63			

SPT=Standard Penetration test	Refusal means SPT N>50	B= No. of blows	R=Rebound	SR: Soft Rock
HR:Hard Rock	DS=Disturbed Sample	CWR: completely weathered rock	MWR: Moderately weathered rock	

Bore hole was terminated at 21.0m depth below existing ground level

GEO ENGINEERING COMPANY PVT. LTD., BANGALORE
An ISO 9001:2015 Company

Client	M/s. BBMP	**BOREHOLE - 04(Old)**	**Size of Borehole**	150mm
Job No	300		**Ground Water Table**	Nil
Project	ROB		**Commenced**	14.06.19
Location	Adugodi to Sarjapur Road Junction		**Completed**	15.06.19

Description of Sub-soil stratum	Depth (m)	Legend	Sample	SPT TEST, number of blows recorded			N Value = N_2+N_3	Core Recovery, %	RQD, %	Remarks
				1st 15cm	2nd 15cm	3rd 15cm				
				N_1	N_2	N_3				
Filled up	0.0									
	0.5		DS							
Reddish sandy Silt	1.5		SPT DS	2	3	4	7			
	3.0		SPT DS	3	5	6	11			
	4.5		SPT DS	5	8	7	15			
Pinkish to brownish grey sandy Silt	6.0		SPT	6	7	8	15			
	7.5		SPT DS	9	10	13	23			
Yellowish to brownish grey sandy Silt	9.0		SPT DS	8	10	11	21			
	10.5		SPT DS	11	14	19	33			
Greenish to brownish grey sandy Silt	12.0		SPT DS	10	14	20	34			
Yellowish to reddish pink SDR	13.5		SPT DS	13	21	30	51			***Refusal Strata***
	15.0		SPT DS	40	50B/1cm	R	>100			
	16.5		SPT DS	40	50B/1cm	R	>100			
	18.0		SPT DS	50B/1cm	R		>100			
	19.5		SPT DS	50B/1cm	R		>100			
	21.0		CR	50B/1cm	R		>100			

SPT=Standard Penetration test	Refusal means SPT N>50	B= No. of blows	R=Rebound	SR: Soft Rock
HR:Hard Rock	DS=Disturbed Sample	CWR: completely weathered rock	MWR: Moderately weathered rock	

Bore hole was terminated at 21.0m depth below existing ground level

GEO ENGINEERING COMPANY PVT. LTD.

LABORATORY TEST REPORT ON SOIL SAMPLES — ANNEXURE III

Client	**M/s. Bengaluru Smart Infrastructure Limited,**	**Project**	**Construction of elevated corridor**	**Job No.**	**722**
Location	**From sholay circle to St. John Hospital**	**Date of Sample Recieved**	**01-02-26**	**Date of Test**	**06-02-26**

BH No.	Sample Type	Sample no.	Depth (m)	Grain Size Distribution (%)					Atterberg Limits (%)			Free Swell Index (%)	IS Classification (IS:1498-1970)	Natural Moisture Content (%)	Bulk Density (gm/cc)	Specific Gravity	Shear Parameters	
				Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt & Clay	Liquid Limit	Plastic Limit	Plasticity Index						Cohession (kN/m^2)	Angle of Internal Friction (deg.)
BH-1 (Koramanagala)	SPT	722/03/01	3.0	0.0	1.9	26.9	9.5	61.7	---	---	---	---	---	20.0	---	---	---	---
	SPT	722/03/02	4.5	0.0	2.4	25.7	9.9	62.0	---	---	---	---	---	17.5	---	---	---	---
	SPT	722/03/03	6.0	1.6	7.6	29.1	11.6	50.1	40.6	---	NP	---	MI	19.1	---	---	---	---
	SPT	722/03/04	7.5	0.8	10.8	21.3	8.6	58.5	---	---	---	---	---	15.8	---	---	---	---
	SPT	722/03/05	10.5	0.0	4.2	33.3	12.7	49.8	---	---	---	---	---	18.2	---	---	---	---
	SPT	722/03/06	13.5	0.0	4.2	35.4	13.6	46.8	---	---	---	---	---	19.7	---	---	---	---
	SPT	722/03/07	15.0	2.9	27.2	64.6	3.4	1.9	---	---	---	---	---	7.2	---	---	---	---
BH-2 (MG Road)	SPT	722/01/01	3.0	0.2	1.5	29.6	19.8	48.9	---	---	---	---	---	17.2	---	---	---	---
	SPT	722/01/02	4.5	4.7	4.8	28.3	13.6	48.6	---	---	---	---	---	18.4	---	---	---	---
	SPT	722/01/03	6.0	0.5	5.7	34.1	17.6	42.1	---	---	---	---	---	16.9	---	---	---	---
	SPT	722/01/04	9.0	3.4	23.1	64.2	7.9	1.4	---	---	---	---	---	15.1	---	---	---	---
	SPT	722/01/05	10.5	5.0	28.5	59.1	5.7	1.7	29.5	---	NP	---	SM	17.9	---	---	---	---
	SPT	722/01/06	12.5	2.0	19.9	65.5	9.3	3.3	---	---	---	---	---	16.5	---	---	---	---
	SPT	722/01/07	15.0	4.6	23.3	64.0	7.8	0.3	---	---	---	---	---	16.7	---	---	---	---

BH No.	Sample Type	Sample no.	Depth (m)	Grain Size Distribution (%)					Atterberg Limits (%)			Free Swell Index (%)	IS Classification (IS:1498-1970)	Natural Moisture Content (%)	Bulk Density (gm/cc)	Specific Gravity	Shear Parameters	
				Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt & Clay	Liquid Limit	Plastic Limit	Plasticity Index						Cohession (kN/m^2)	Angle of Internal Friction (deg.)
BH-3 (Audugodi)	SPT	722/02/01	3.0	1.0	4.6	33.6	16.8	44.0	32.4	14.5	17.9	---	SC	15.9	---	---	---	---
	SPT	722/02/02	4.5	1.2	3.1	30.2	15.4	50.1	---	---	---	---	---	18.1	---	---	---	---
	SPT	722/02/03	6.0	0.2	5.1	33.6	16.6	44.5	---	---	---	---	---	18.5	---	---	---	---
	SPT	722/02/04	7.5	3.3	18.2	63.5	12.6	2.4	---	---	---	---	---	13.8	---	---	---	---
	SPT	722/02/05	9.0	3.1	8.5	59.2	13.0	16.2	---	---	---	---	---	18.8	---	---	---	---
	SPT	722/02/06	12.0	1.9	29.1	62.7	4.1	2.2	---	---	---	---	---	10.1	---	---	---	---
	SPT	722/02/07	15.0	2.4	28.4	63.3	3.6	2.3	---	---	---	---	---	10.0	---	---	---	---
1 (Old)	SPT	300/1	1.5	0.9	4.5	19.0	27.7	47.9	---	---	---	---	---	15.5	---	---	---	---
	SPT	300/2	3.0	0.0	4.4	34.2	16.9	44.5	44.3	---	NP		SM-MI	22.5	---	---	---	---
	SPT	300/3	6.0	0.1	13.4	52.5	13.6	20.4	---	---	---	---	---	9.8	---	---	---	---
	SPT	300/4	7.5	0.5	8.8	66.6	19.7	4.4	---	---	---	---	---	12.3	---	---	---	---
2 (Old)	SPT	300/5	1.5	0.0	0.8	23.8	20.9	54.5	---	---	---	---	---	28.1	---	---	---	---
	SPT	300/6	4.5	0.0	1.6	27.1	16.5	54.8	43.8	---	NP	---	MI	24.5	---	---	---	---
	SPT	300/7	9.0	0.0	3.8	32.9	17.4	45.9	---	---	---	---	---	22.8	---	---	---	---
	SPT	300/8	12.0	0.0	2.4	17.7	17.9	62.0	---	---	---	---	---	23.5	---	---	---	---
	SPT	300/9	15.0	0.0	3.4	24.8	13.8	58.0	---	---	---	---	---	19.9	---	---	---	---
	SPT	300/10	16.5	1.3	20.5	75.1	2.3	0.8	---	---	---	---	---	2.9	---	---	---	---
	SPT	300/11	17.5	0.2	16.0	78.6	4.6	0.6	---	---	---	---	---	1.1	---	---	---	---
3 (Old)	SPT	300/12	1.5	0.1	13.9	32.8	9.0	44.2	40.8	20.9	19.8	---	SM-MI	10.7	---	---	---	---
	SPT	300/13	3.0	0.0	5.5	30.2	7.5	56.8	---	---	---	---	---	9.6	---	---	---	---
	SPT	300/14	4.5	0.4	13.3	26.3	7.6	52.4	---	---	---	---	---	18.6	---	---	---	---
	SPT	300/15	7.5	0.8	4.0	26.8	13.2	55.2	---	---	---	---	---	23.5	---	---	---	---

BH No.	Sample Type	Sample no.	Depth (m)	Grain Size Distribution (%)					Atterberg Limits (%)			Free Swell Index (%)	IS Classification (IS:1498-1970)	Natural Moisture Content (%)	Bulk Density (gm/cc)	Specific Gravity	Shear Parameters	
				Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt & Clay	Liquid Limit	Plastic Limit	Plasticity Index						Cohession (kN/m^2)	Angle of Internal Friction (deg.)
3 (Old)	SPT	300/16	10.5	0.0	4.4	36.3	13.6	45.7	---	---	---	---	---	22.2	---	---	---	---
	SPT	300/17	12.0	0.0	7.3	36.7	12.0	44.0	---	---	---	---	---	20.4	---	---	---	---
	SPT	300/18	16.5	0.4	14.8	81.1	3.1	0.6	---	---	---	---	---	13.6	---	---	---	---
	SPT	300/19	18.0	0.1	5.6	36.4	11.3	46.6	---	---	---	---	---	18.2	---	---	---	---
	SPT	300/20	19.5	1.9	3.3	33.9	10.2	50.7	---	---	---	---	---	13.2	---	---	---	---
4 (Old)	SPT	300/21	1.5	7.3	4.1	14.0	24.9	49.7	---	---	---	---	---	16.5	---	---	---	---
	SPT	300/22	3.0	2.9	2.6	13.9	24.6	56.0	37.6	20.5	17.1	---	MI	18.1	---	---	---	---
	SPT	300/23	6.0	0.0	5.2	32.3	9.7	52.8	---	---	---	---	---	20.5	---	---	---	---
	SPT	300/24	9.0	0.1	2.0	28.4	11.5	58.0	---	---	---	---	---	26.6	---	---	---	---
	SPT	300/25	12.0	0.6	3.4	32.5	10.4	53.1	---	---	---	---	---	23.5	---	---	---	---
	SPT	300/26	13.5	0.6	9.1	75.4	3.6	11.3	---	---	---	---	---	9.7	---	---	---	---
	SPT	300/27	16.5	1.0	23.8	67.4	6.4	1.4	---	---	---	---	---	10.9	---	---	---	---
	SPT	300/28	19.0	0.3	25.5	70.3	3.7	0.2	---	---	---	---	---	7.0	---	---	---	---
	SPT	300/29	21.0	0.6	19.8	72.4	5.8	1.4	---	---	---	---	---	7.2	---	---	---	---

This report relates only to the sample tested and shall not be reproduced except in full without written approval of laboratory management

Authorised Signatory

Abrreviations used: UDS: Undisturbed Sample, DS: Disturbed Sample, SPT: Standard Penetration Test, BH: Bore Hole, NP: Non Plastic

Test Method Referred to:	Grain Size Distribution: IS 2720-4 1985 RA 2015	Liquid and Plastic Limit: IS 2720-5 1985 RA 2015	Specific Gravity: IS 2720-3 SECTION 1 & 2
	Direct Shear Test: IS 2720-13 1986 RA 2016	Free Swell Index: IS 2720-40 1977 RA 2016	Natural Moisture Content: IS 2720-2 1973
Test Method Variation :	None		

ANNEXURE IV

GRAIN SIZE ANALYSIS CURVES

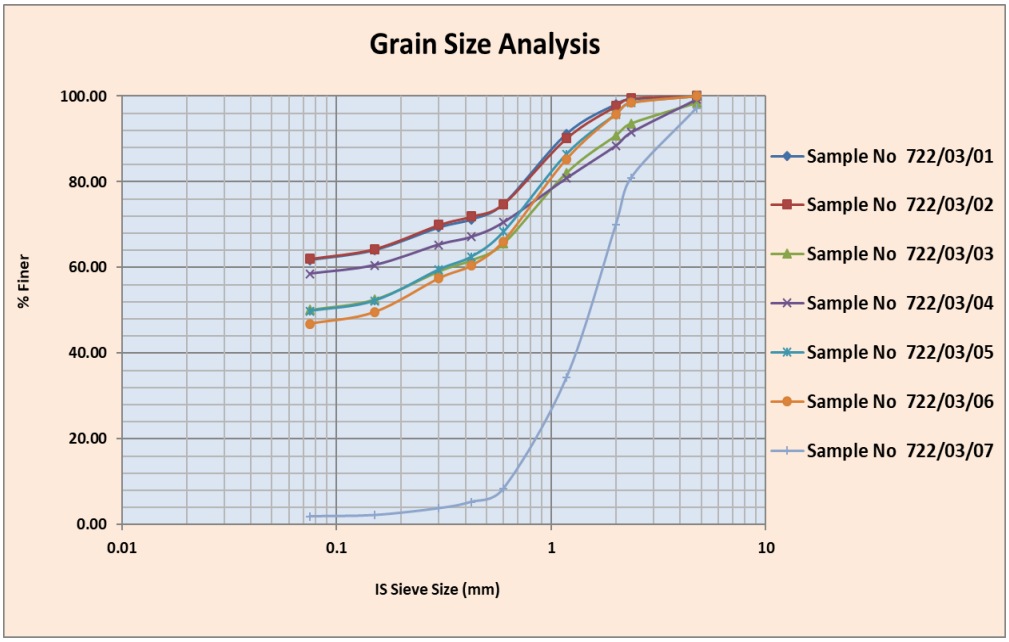


Fig. No.1: Grain size analysis Curves around BH 01(Kormangala)

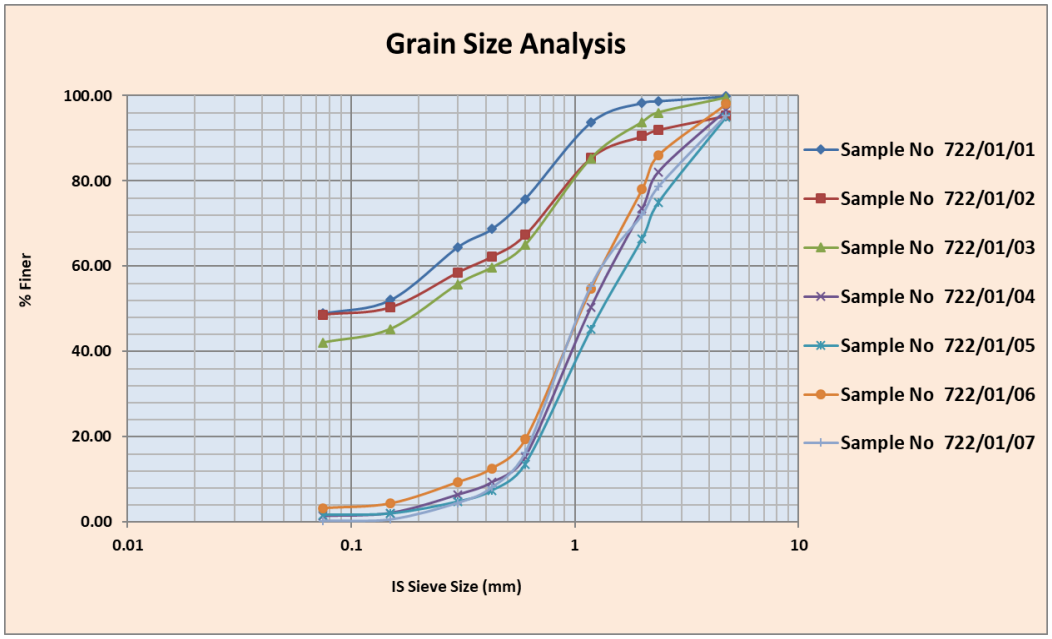


Fig. No.2: Grain size analysis Curves around BH 02(MG Road)

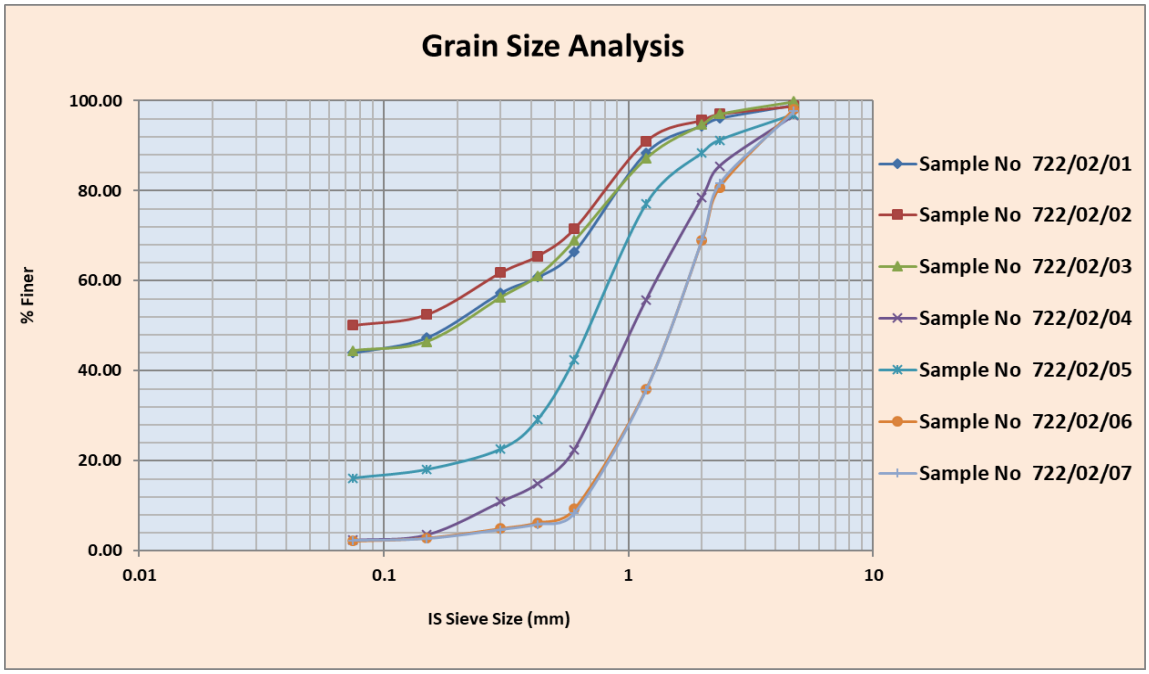


Fig. No.3: Grain size analysis Curves around BH 03 (Audugodi)

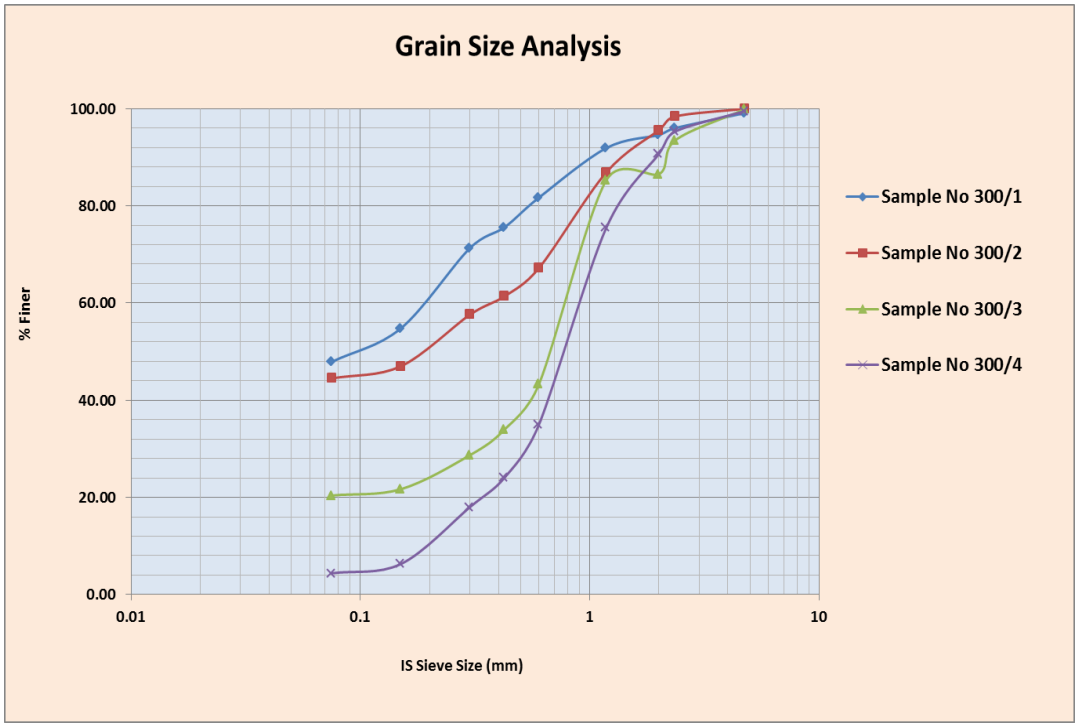


Fig. No.4: Grain size analysis Curves around BH 1(Old)

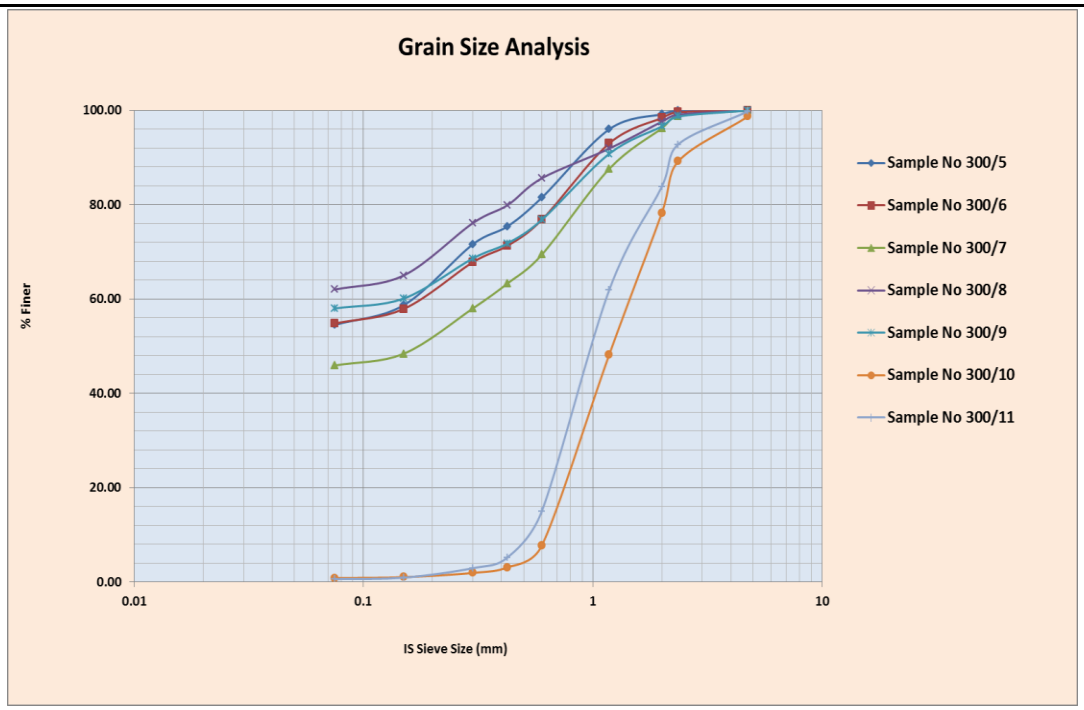


Fig. No.5: Grain size analysis Curves around BH 2(Old)

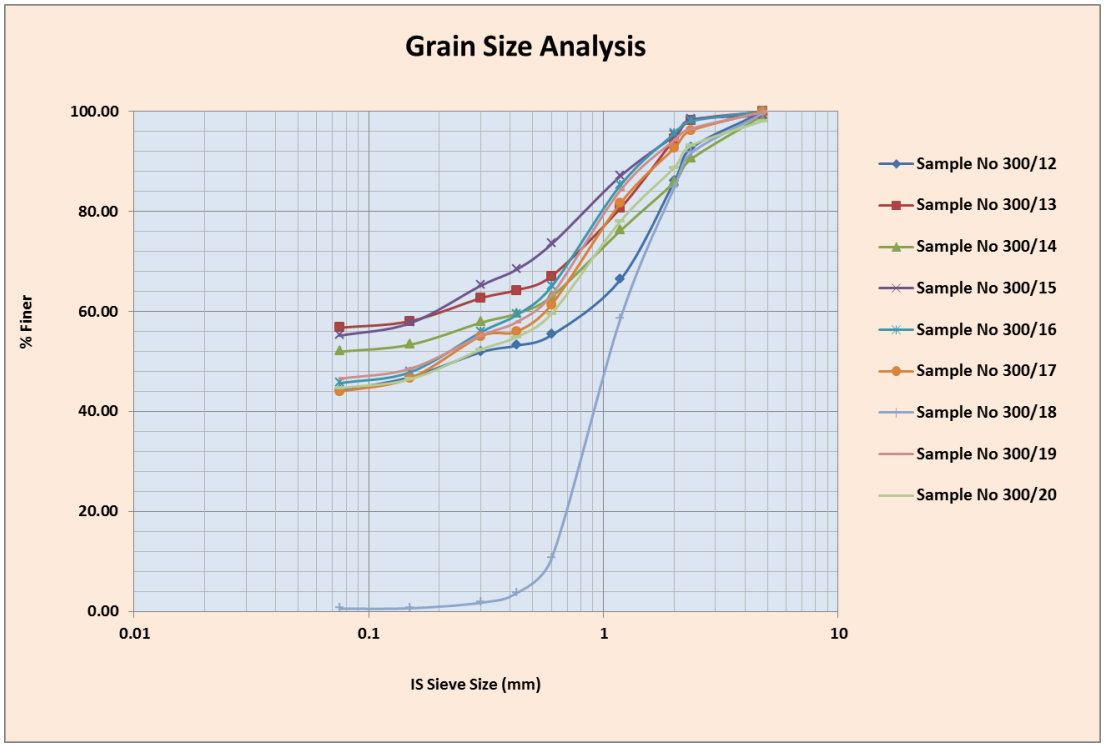


Fig. No.6: Grain size analysis Curves around BH 3(Old)

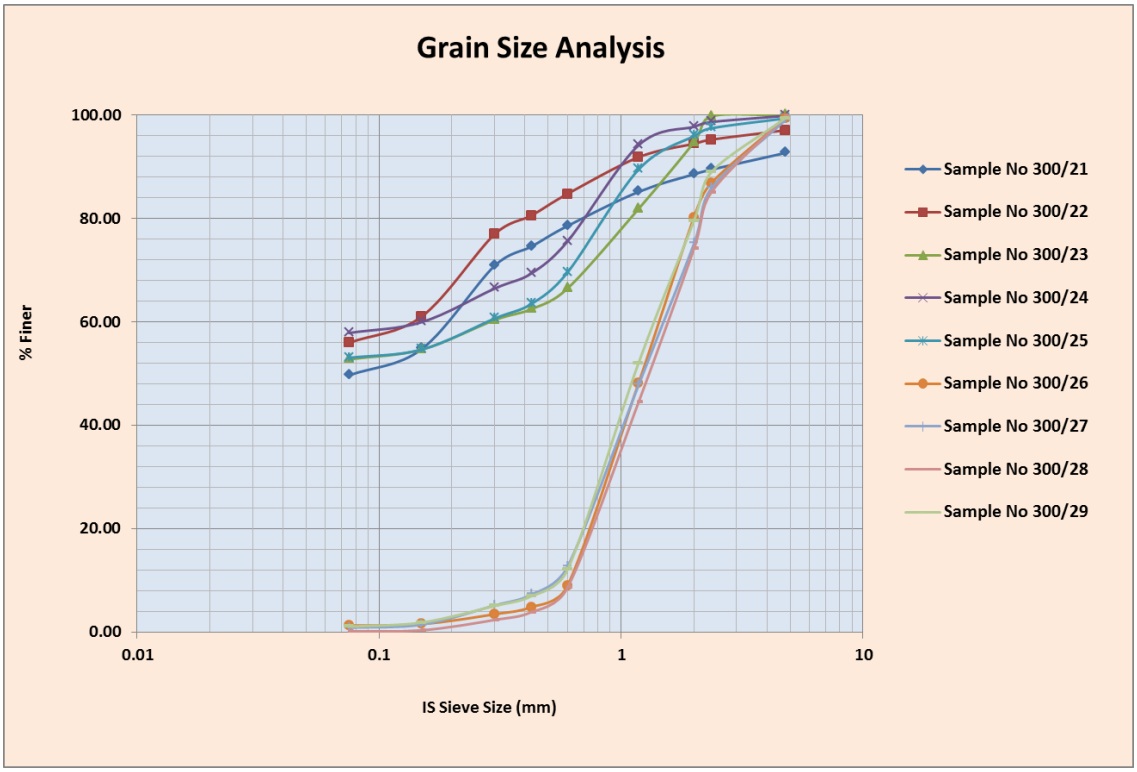


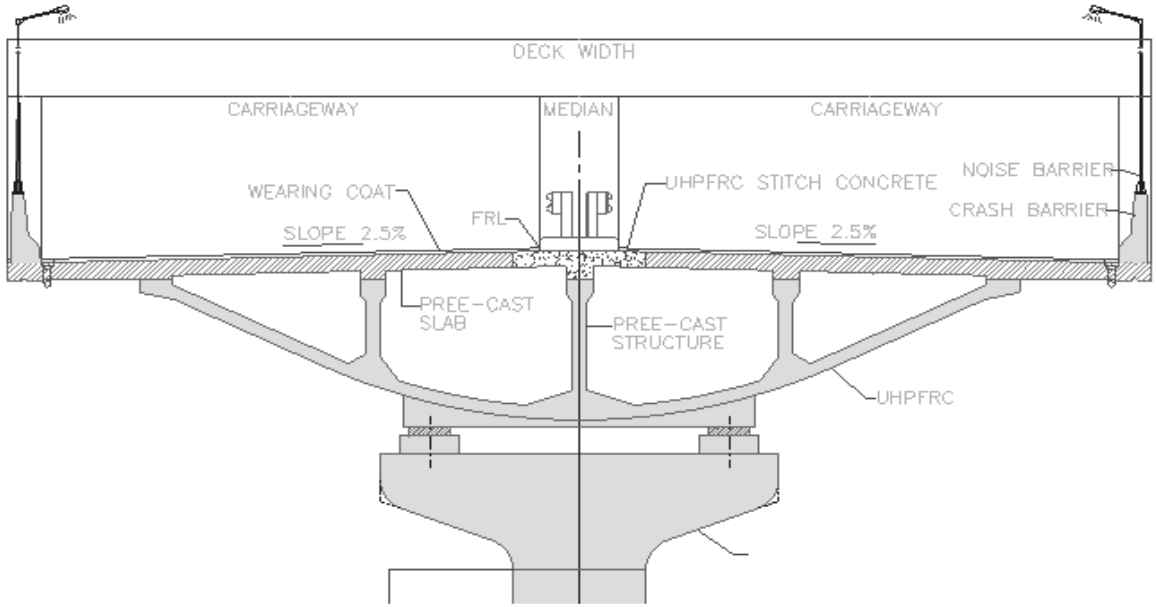
Fig. No.7: Grain size analysis Curves around BH 4(Old)

*****END OF REPORT*****

APPENDIX - 3 – PRELIMINARY DESIGN REPORT

Preliminary Design of Fish Belly Superstructure – 50m Span and 17.2m deck width

Design of Fish Belly Superstructure ***For 50m Span***



3. Data for Design

			Proposed Section				
Span of Bridge (C/C of bearings)		=	48400	mm			
C/C of piers		=	50000	mm			
Carriageway Width		=	15200	mm			
O/O of Parapet		=	17200	mm			
CantileverProjection		=	1982	mm			
Width of Bottom Slab		=	5300	mm	4500	mm is the c/c of bearing	
Angle of inclination for the Webs.		=	26.000	^{0}	0.45	^{c}	
Thickness of Deck Slab		=	250	mm			
Thickness of Slab at cant. Tip		=	300	mm			
Thickness of Slab at cant. Face		=	300	mm			
Overall Depth of the Girder	Maximum Depth	=	2712	mm			
Thickness of Soffit Slab (Running X^n)		=	200	mm			
Thickness of Soffit Slab (End X^n)		=	200	mm			
Web thickness (Running X^n)		=	200	mm	456.23	eff.	
Web thickness (End X^n)		=	200	mm	456.23	eff.	
Diaphragm present at end or not		=	y	(Y/N)			
If yes, Thickness of diaphragm		=	1000	mm			
Over hang of girder beyond bearings		L1 =	400	mm	0	mm will be grouted later	
Overhang beyond end diaphragm			810	mm			
Crash Barrier			500	X	1000	X	4 side/s
Crash Barrier Load			8.0	kN/m			
Median Load			11.0	kN/m			
Working Point =			150	mm			
Density of Concrete		=	25	KN/m^3			
Intensity of wearing coat load considered =			2	KN/m^2			
Grade of Concrete Used For Box Girder		= M	150				
Characteristic Compressive Strength		=	150	N/mm^2			
Permissible stress in Concrete.		=	85	N/mm^2	CL 3.1.6 NF P18 - 710		
Modulus of Elasticity of Concrete "Ecm" of girder		=	47270	N/mm^2			
Modulus of Elasticity of Concrete "Ecm" of Top Slab		=	35000	N/mm^2			
Modular Ratio		=	0.7404				
HTS steel used in design :	Uncoated stress relieved low relaxation steel conforming to IS:14268						
Modulus of Elasticity of Steel "Es"		=	195000	MPa.			
Area of strand		=	140	mm^2			
Type of cable	= 19	T	15	with duct diameter			

Section Properties *(Composite section properties considering difference in Youngs Modulus of Top Slab and U trough)*													
Distance (x)		0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.200
Section Properties													
Area		9.6E+06	9.6E+06	9.6E+06	9.6E+06	9.6E+06	9.6E+06	7.9E+06	7.9E+06	7.9E+06	7.9E+06	7.9E+06	7.9E+06
Section CG(y)		1662.0	1662.0	1662.0	1662.0	1662.0	1662.0	1798.0	1798.0	1798.0	1798.0	1798.0	1798.0
I section		7.51	7.51	7.51	7.51	7.51	7.51	6.03	6.03	6.03	6.03	6.03	6.03
Zt		7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15
Zb		4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52
Section Area		9.56	9.56	9.56	9.56	9.56	9.56	7.94	7.94	7.94	7.94	7.94	7.94
Actual Cross sectional area =		10.49	10.49	10.49	10.49	10.49	10.49	9.13	9.13	9.13	9.13	9.13	9.13

5) Summary of Forces & bending stress calculation

i) Dead Load Stress Resultants from Midas Civil (Includes SW of U trough, Top Slab)

	Section No.	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12	
	Section at	Support	1st Junction	2nd Junction	3rd Junction	4th Junction	5th Junction	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2	
	Node Numbers	8	9	10	11	12	13	14	15	16	17	18	19	
	Distance (x)	0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.2	
P(x)	Shear (kN)	5853.20	5722.08	5538.50	5014.00	4358.38	3697.17	3089.41	2403.91	1718.41	1032.91	347.41	4.66	
	BM (kNm)	288.25	2605.57	6546.78	17099.28	28814.76	38891.17	47363.79	55603.75	61787.22	65914.19	67984.65	68248.70	
	Zt	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	7.15	
	Zb	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	4.52	
Bending Stresses	Top Stress	0.03	0.27	0.68	1.77	2.98	4.03	4.90	5.76	6.40	6.83	7.04	7.07	Mpa
	Bottom Stress	-0.06	-0.58	-1.45	-3.79	-6.38	-8.61	-10.48	-12.31	-13.68	-14.59	-15.05	-15.11	Mpa

Stress Resultants from Midas for 4 Lane Loading

	Section No.	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
	Section at	**Support**	**1st Junction**	**2nd Junction**	**3rd Junction**	**4th Junction**	**5th Junction**	**6th Junction**	**7th Junction**	**8th Junction**	**9th Junction**	**10th Junction**	**L/2**
	Node Numbers	8	9	10	11	12	13	14	15	16	17	18	19
	Distance (x)	0	0.500	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
Shear due to Crash Barrier(KN)		546.92	535.62	519.80	474.60	418.10	361.60	305.10	237.30	169.50	101.70	33.90	0.00
Shear due to Wearing Coat(KN)		726.00	711.00	690.00	630.00	555.00	480.00	405.00	315.00	225.00	135.00	45.00	0.00
Shear due to Footpath LL (kNm)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BM due to Crash Barrier(KN)		6.79	263.85	633.25	1627.65	2743.52	3718.15	4551.52	5365.12	5975.32	6382.12	6585.52	6610.95
BM due to Wearing Coat(KN)		9.01	350.24	840.59	2160.59	3641.84	4935.59	6041.84	7121.84	7931.84	8471.84	8741.84	8775.59
BM due to Footpath LL (kNm)		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bending Stress due to Crash Barrier(kNm)	Top Stress	0.00	0.03	0.07	0.17	0.28	0.39	0.47	0.56	0.62	0.66	0.68	0.68
	Bottom Stress	0.00	-0.06	-0.14	-0.36	-0.61	-0.82	-1.01	-1.19	-1.32	-1.41	-1.46	-1.46

Bending Stress due to Wearing Coat (kNm)	Top Stress	0.00	0.04	0.09	0.22	0.38	0.51	0.63	0.74	0.82	0.88	0.91	0.91
	Bottom Stress	0.00	-0.08	-0.19	-0.48	-0.81	-1.09	-1.34	-1.58	-1.76	-1.88	-1.94	-1.94
Bending Stress due to Footpath LL (kNm)	Top Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Bottom Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Shear (kN)	1272.92	1246.62	1209.80	1104.60	973.10	841.60	710.10	552.30	394.50	236.70	78.90	0.00
Total Bending Stresses(kNm)	Top Stress	0.00	0.06	0.15	0.39	0.66	0.90	1.10	1.29	1.44	1.54	1.59	1.59
	Bottom Stress	0.00	-0.14	-0.33	-0.84	-1.41	-1.92	-2.34	-2.76	-3.08	-3.29	-3.39	-3.41
	Torsion(KNm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00

Section No.	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
Section at	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Node Numbers	18	19	20	21	22	23	24	25	26	27	30
Distance (x)	25.700	28.700	31.700	34.700	37.700	40.200	42.700	42.700	47.200	47.900	48.400
Shear due to Crash Barrier(KN)	33.90	101.70	169.50	237.30	305.10	361.60	418.10	474.60	519.80	535.62	546.92
Shear due to Wearing Coat(KN)	45.00	135.00	225.00	315.00	405.00	480.00	555.00	630.00	690.00	711.00	726.00
Shear due to Footpath LL (kNm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BM due to Crash Barrier(KN)	6585.52	6382.12	5975.32	5365.12	4551.52	3718.15	2743.52	1627.65	633.25	263.85	6.79
BM due to Wearing Coat(KN)	8741.84	8471.84	7931.84	7121.84	6041.84	4935.59	3641.84	2160.59	840.59	350.24	9.01
BM due to Footpath LL (kNm)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bending Stress due to Crash Barrier(kNm)	Top Stress	0.68	0.66	0.62	0.56	0.47	0.39	0.28	0.17	0.07	0.03	0.00
	Bottom Stress	-1.46	-1.41	-1.32	-1.19	-1.01	-0.82	-0.61	-0.36	-0.14	-0.06	0.00
Bending Stress due to Wearing Coat (kNm)	Top Stress	0.91	0.88	0.82	0.74	0.63	0.51	0.38	0.22	0.09	0.04	0.00
	Bottom Stress	-1.94	-1.88	-1.76	-1.58	-1.34	-1.09	-0.81	-0.48	-0.19	-0.08	0.00
Bending Stress due to Footpath LL (kNm)	Top Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Bottom Stress	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total Shear (kN)	78.90	236.70	394.50	552.30	710.10	841.60	973.10	1104.60	1209.80	1246.62	1272.92
Total Bending Stresses(kNm)	Top Stress	1.59	1.54	1.44	1.29	1.10	0.90	0.66	0.39	0.15	0.06	0.00
	Bottom Stress	-3.39	-3.29	-3.08	-2.76	-2.34	-1.92	-1.41	-0.84	-0.33	-0.14	0.00
	Torsion(KNm)	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Maximum Summary of 4 Lanes VLL Forces from Midas Civil

		1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
		Support	1st Junction	2nd Junction	3rd Junction	4th Junction	5th Junction	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
	Node Numbers	8	9	10	11	12	13	14	15	16	17	18	19
	Distance (x)	0	0.500	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
	Shear (kN)	1659.6	1659.6	1531.8	1510.4	1347.4	1229.5	1133.6	1037.8	935.4	795.6	654.5	654.5
	BM (kNm)	277.3	829.8	1924.3	4791.7	8139.6	10695.1	12914.6	15093.7	16690.2	17725.6	18123.8	18107.2
Bending Stress (MPa)	Top Stress	0.03	0.09	0.20	0.50	0.84	1.11	1.34	1.56	1.73	1.84	1.88	1.87
	Bottom Stress	-0.06	-0.18	-0.43	-1.06	-1.80	-2.37	-2.86	-3.34	-3.69	-3.92	-4.01	-4.01
	Torsion (kNm)	1369.2	1369.2	1263.7	1246.1	1111.6	1014.3	935.2	856.2	771.7	656.4	539.9	539.92

		13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
		11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
	Distance (x)	25.7	28.7	31.7	34.7	37.7	40.2	42.7	42.7	47.2	47.9	48.4
	Shear (kN)	654.5	795.6	935.4	1037.8	1133.6	1229.5	1347.4	1510.4	1531.8	1659.6	1659.6
	BM (kNm)	18123.8	17725.6	16690.2	15093.7	12914.6	10695.1	8139.6	4791.7	1924.3	829.8	277.3
Bending Stress (MPa)	Top Stress	1.88	1.84	1.73	1.56	1.34	1.11	0.84	0.50	0.20	0.09	0.03
	Bottom Stress	-4.01	-3.92	-3.69	-3.34	-2.86	-2.37	-1.80	-1.06	-0.43	-0.18	-0.06
	Torsion (kNm)	539.9	656.4	771.7	856.2	935.2	1014.3	1111.6	1246.1	1263.7	1369.2	1369.2

Stresses due to 23 cables Prestressing force after instantneous losses (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
	Support	1st Junction	2nd Junction	3rd Junction	4th Junction	5th Junction	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0	0.5	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
Axial Force (P)	78801	78896	79023	79407	79864	80400	81380	81860	82268	82273	81868	81641.9
BM (P*e)	47758	49395	51686	58305	66642	74581	87253	87772	88231	88334	87916	87673.0
Top Stress	1.16	1.00	0.77	0.11	-0.71	-1.49	-1.45	-1.46	-1.46	-1.47	-1.47	-1.5
Bottom Stress	18.82	19.19	19.71	21.21	23.11	24.92	29.56	29.74	29.89	29.92	29.77	29.7

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Axial Force (P)	81868	82273	82268	81860	81380	80400	79864	79407	79023	78896	78801
BM (P*e)	87916	88334	88231	87772	87253	74581	66642	58305	51686	49395	47758
Top Stress	-1.47	-1.47	-1.46	-1.46	-1.45	-1.49	-0.71	0.11	0.77	1.00	1.16
Bottom Stress	29.77	29.92	29.89	29.74	29.56	24.92	23.11	21.21	19.71	19.19	18.82

Stresses due to 23 cables Prestressing force after all losses (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Distance (x)	8	9	10	11	12	13	14	15	16	17	18	19
Node Number	0	0.5	1.2	3.2	5.7	8.2	10.7	13.7	16.7	19.7	22.7	24.2
Axial Force (P)	76065	76164	76299	76707	77207	77767	78892	79396	79816	79859	79517.19	79317.1
BM (P*e)	46145	47737	49964	56399	64510	72230	84710	85269	85750	85890	85541.47	85326.3
Top Stress	1.11	0.96	0.74	0.10	-0.70	-1.46	-1.41	-1.43	-1.44	-1.45	-1.44	-1.4
Bottom Stress	18.17	18.54	19.04	20.51	22.36	24.13	28.69	28.87	29.03	29.07	28.95	28.9

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Axial Force (P)	79517	79859	79816	79396	78892	77767	77207	76707	76299	76164	76065
BM (P*e)	85541	85890	85750	85269	84710	72230	64510	56399	49964	47737	46145
Top Stress	-1.44	-1.45	-1.44	-1.43	-1.41	-1.46	-0.70	0.10	0.74	0.96	1.11
Bottom Stress	28.95	29.07	29.03	28.87	28.69	24.13	22.36	20.51	19.04	18.54	18.17

Temperature Gradient Rise (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0	0.6	3.3	6.2	9.1	12.2	15.52	18.84	22.16	25.48	26.48	28.800
Top Stress	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18
Bottom Stress	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Top Stress	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18	-1.18
Bottom Stress	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20

Temperature Gradient Fall (from Midas)

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0	0.6	3.3	6.2	9.1	12.2	15.52	18.84	22.16	25.48	26.48	28.800
Top Stress	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Bottom Stress	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64

	13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
	11th Junction	12th Junction	13th Junction	14th Junction	15th Junction	16th Junction	17th Junction	18th Junction	19th Junction	20th Junction	Support
Top Stress	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Bottom Stress	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64

Rare Combination 4 Lanes :- DL x 1.0 + CB(4L) x 1.0 + WC(4L) x 1.2 + VLL(4L) x 1.0 + Differential Shrinkage x 0.6

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.200
Shear (kN)	8930.96	8770.54	8418.06	7754.98	6789.87	5864.23	5014.13	4057	3093.33	2092.22	1089.76	659.11
BM (kNm)	2443.77	5980.13	11973.68	27971.98	45928.67	61087.71	73940.68	86469.40	95831.59	102048.70	105044.79	105358.17

Factored 4 Lanes :- DL x 1.35 + CB(4L) x 1.35 + WC(4L) x 1.75 + VLL(4L) x 1.5 + Differential Shrinkage x 0.9

	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	11--11
	Support	1st Junction	2nd Junction	3rd Junction	Taper Start	Taper end	6th Junction	7th Junction	8th Junction	9th Junction	10th Junction	L/2
Node Number	8	9	10	11	12	13	14	15	16	17	18	19
Distance (x)	0.000	0.500	1.200	3.200	5.700	8.200	10.700	13.700	16.700	19.700	22.700	24.200
Shear (kN)	12400.122	12181.605	11683.845	10777.68	9440.583	8163.53	6991.7685	5673.5685	4345.5585	2961.3885	1575.1935	987.97
BM (kNm)	3621.0	8522.3	16841.5	39040.9	63977.2	84993.4	102821.6	120202.7	133186.4	141805.0	145944.6	146369.53

7) Check for Stresses

Time Dependent Losses consisting of the following :-

1) DL + PS 23 cables (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load *1* *Minimum Allowable Compression =* *0.5 Mpa (At joints)*

Prestressing *1* *Minimum Allowable Compression =* *0 Mpa (At other locations)*

Maximum Allowable Compression = *85 Mpa CL 3.1.6 NF P18 - 710*

		1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
Distance (x)		0.00	0.50	1.20	3.20	5.70	8.20	10.70	13.70	16.70	19.70	22.70	24.20
Prestress	s t	1.16	1.00	0.77	0.11	-0.71	-1.49	-1.45	-1.46	-1.46	-1.47	-1.47	-1.47
	s b	18.82	19.19	19.71	21.21	23.11	24.92	29.56	29.74	29.89	29.92	29.77	29.69
Dead Load	s t	0.03	0.27	0.68	1.77	2.98	4.03	4.90	5.76	6.40	6.83	7.07	7.07
	s b	-0.06	-0.58	-1.45	-3.79	-6.38	-8.61	-10.48	-12.31	-13.68	-14.59	-15.11	-15.11
Resultant	**s t**	**1.19**	**1.27**	**1.45**	**1.88**	**2.27**	**2.53**	**3.46**	**4.30**	**4.93**	**5.35**	**5.60**	**5.60**
	s b	**18.75**	**18.61**	**18.26**	**17.43**	**16.73**	**16.31**	**19.08**	**17.43**	**16.21**	**15.32**	**14.66**	**14.58**

		13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
Distance (x)		25.7	28.7	31.7	34.7	37.7	40.2	42.7	42.7	47.2	47.9	48.4
Prestress	s t	-1.47	-1.47	-1.46	-1.46	-1.45	-1.49	-0.71	0.11	0.77	1.00	1.16
	s b	29.77	29.92	29.89	29.74	29.56	24.92	23.11	21.21	19.71	19.19	18.82
Dead Load	s t	7.07	6.83	6.40	5.76	4.90	4.03	2.98	1.77	0.68	0.27	0.03
	s b	-15.11	-14.59	-13.68	-12.31	-10.48	-8.61	-6.38	-3.79	-1.45	-0.58	-0.06
Resultant	**s t**	**5.60**	**5.35**	**4.93**	**4.30**	**3.46**	**2.53**	**2.27**	**1.88**	**1.45**	**1.27**	**1.19**
	s b	**14.66**	**15.32**	**16.21**	**17.43**	**19.08**	**16.31**	**16.73**	**17.43**	**18.26**	**18.61**	**18.75**

2) DL + PS 23 Cables + Temperature Fall (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load 1 *Minimum Allowable Compression =* *0.5 Mpa (At joints)*

Prestressing 1 *Minimum Allowable Compression =* *0 Mpa (At other locations)*

Temperature Fall 1 *Maximum Allowable Compression =* *85 Mpa CL 3.1.6 NF P18 - 710*

		1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	11--11	12--12
Distance (x)		0.00	0.50	1.20	3.20	5.70	8.20	10.70	13.70	16.70	19.70	22.70	24.20
Prestress	s t	1.16	1.00	0.77	0.11	-0.71	-1.49	-1.45	-1.46	-1.46	-1.47	-1.47	-1.47
	s b	18.82	19.19	19.71	21.21	23.11	24.92	29.56	29.74	29.89	29.92	29.77	29.69
Dead Load	s t	0.03	0.27	0.68	1.77	2.98	4.03	4.90	5.76	6.40	6.83	7.07	7.07
	s b	-0.06	-0.58	-1.45	-3.79	-6.38	-8.61	-10.48	-12.31	-13.68	-14.59	-15.11	-15.11
Temperature	s t	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
	s b	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
Resultant	s t	**2.39**	**2.47**	**2.65**	**3.08**	**3.47**	**3.73**	**4.66**	**5.50**	**6.13**	**6.55**	**6.80**	**6.80**
	s b	**20.39**	**20.25**	**19.90**	**19.07**	**18.37**	**17.95**	**20.72**	**19.07**	**17.85**	**16.96**	**16.30**	**16.22**

		13--13	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23

Distance (x)		*25.7*	*28.7*	*31.7*	*34.7*	*37.7*	*40.2*	*42.7*	*42.7*	*47.2*	*47.9*	*48.4*
Prestress	s t	*-1.47*	*-1.47*	*-1.46*	*-1.46*	*-1.45*	*-1.49*	*-0.71*	*0.11*	*0.77*	*1.00*	*1.16*
	s b	*29.77*	*29.92*	*29.89*	*29.74*	*29.56*	*24.92*	*23.11*	*21.21*	*19.71*	*19.19*	*18.82*
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Resultant	s t	***6.80***	***6.55***	***6.13***	***5.50***	***4.66***	***3.73***	***3.47***	***3.08***	***2.65***	***2.47***	***2.39***
	s b	***16.30***	***16.96***	***17.85***	***19.07***	***20.72***	***17.95***	***18.37***	***19.07***	***19.90***	***20.25***	***20.39***

3) DL + PS 23 Cables + Temp Fall + 2 Lane CB (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load	1	*Minimum Allowable Compression =*	*0.5 Mpa (At joints)*
Prestressing	1	*Minimum Allowable Compression =*	*0 Mpa (At other locations)*
Crash Barrier	1	*Maximum Allowable Compression =*	*85 Mpa CL 3.1.6 NF P18 - 710*
Temperature Fall	1		

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***
Distance (x)		*0*	*0.5*	*1.20*	*3.2*	*5.7*	*8.2*	*10.7*	*13.7*	*16.7*	*19.7*	*22.70*	*24.2*
Prestress	s t	*1.16*	*1.00*	*0.77*	*0.11*	*-0.71*	*-1.49*	*-1.45*	*-1.46*	*-1.46*	*-1.47*	*-1.47*	*-1.47*
	s b	*18.82*	*19.19*	*19.71*	*21.21*	*23.11*	*24.92*	*29.56*	*29.74*	*29.89*	*29.92*	*29.77*	*29.69*
Dead Load	s t	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*
	s b	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s t	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*
	s b	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*
Resultant	s t	***2.39***	***2.49***	***2.71***	***3.25***	***3.75***	***4.12***	***5.13***	***6.06***	***6.75***	***7.21***	***7.48***	***7.49***
	s b	***20.39***	***20.19***	***19.76***	***18.70***	***17.76***	***17.13***	***19.71***	***17.88***	***16.53***	***15.55***	***14.84***	***14.75***

		13--13	***14--14***	***15--15***	***16--16***	***17--17***	***18--18***	***19--19***	***20--20***	***21--21***	***22--22***	***23--23***
Distance (x)		*25.7*	*28.7*	*31.7*	*34.7*	*37.7*	*40.2*	*42.7*	*42.7*	*47.2*	*47.9*	*48.4*
Prestress	s t	*-1.47*	*-1.47*	*-1.46*	*-1.46*	*-1.45*	*-1.49*	*-0.71*	*0.11*	*0.77*	*1.00*	*1.16*
	s b	*29.77*	*29.92*	*29.89*	*29.74*	*29.56*	*24.92*	*23.11*	*21.21*	*19.71*	*19.19*	*18.82*
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s t	*0.68*	*0.66*	*0.62*	*0.56*	*0.47*	*0.39*	*0.28*	*0.17*	*0.07*	*0.03*	*0.00*
	s b	*-1.46*	*-1.41*	*-1.32*	*-1.19*	*-1.01*	*-0.82*	*-0.61*	*-0.36*	*-0.14*	*-0.06*	*0.00*
Resultant	s t	***7.48***	***7.21***	***6.75***	***6.06***	***5.13***	***4.12***	***3.75***	***3.25***	***2.71***	***2.49***	***2.39***
	s b	***14.84***	***15.55***	***16.53***	***17.88***	***19.71***	***17.13***	***17.76***	***18.70***	***19.76***	***20.19***	***20.39***

4) DL + PS 23 Cables + Temp Fall + 2 Lane SIDL (After Instantaneous Losses)

Load factors as Per Table 3.3 of IRC 6-2016

Dead Load	1	*Minimum Allowable Compression =*	*0.5 Mpa (At joints)*
Prestressing	1	*Minimum Allowable Compression =*	*0 Mpa (At other locations)*
Crash Barrier	1	*Maximum Allowable Compression =*	*85 Mpa CL 3.1.6 NF P18 - 710*
Wearing Coat	1.2		
Temperature Fall	1		

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***
Distance (x)		***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***24.2***
Prestress	s t	*1.16*	*1.00*	*0.77*	*0.11*	*-0.71*	*-1.49*	*-1.45*	*-1.46*	*-1.46*	*-1.47*	*-1.47*	*-1.47*
	s b	*18.82*	*19.19*	*19.71*	*21.21*	*23.11*	*24.92*	*29.56*	*29.74*	*29.89*	*29.92*	*29.77*	*29.69*

Dead Load	s *t*	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*
	s *b*	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*
Temperature	s *t*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s *b*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s *t*	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*
	s *b*	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*
Wearing Coat	s *t*	*0.00*	*0.04*	*0.09*	*0.22*	*0.38*	*0.51*	*0.63*	*0.74*	*0.82*	*0.88*	*0.91*	*0.91*
	s *b*	*0.00*	*-0.08*	*-0.19*	*-0.48*	*-0.81*	*-1.09*	*-1.34*	*-1.58*	*-1.76*	*-1.88*	*-1.94*	*-1.94*
Resultant	s *t*	***2.39***	***2.54***	***2.82***	***3.52***	***4.21***	***4.73***	***5.88***	***6.94***	***7.74***	***8.26***	***8.56***	***8.58***
	s *b*	***20.38***	***20.10***	***19.53***	***18.13***	***16.79***	***15.81***	***18.10***	***15.99***	***14.42***	***13.30***	***12.52***	***12.42***

		13--13	***14--14***	***15--15***	***16--16***	***17--17***	***18--18***	***19--19***	***20--20***	***21--21***	***22--22***	***23--23***
Distance (x)		***25.7***	***28.7***	***31.7***	***34.7***	***37.7***	***40.2***	***42.7***	***42.7***	***47.2***	***47.9***	***48.4***
Prestress	*s t*	*-1.47*	*-1.47*	*-1.46*	*-1.46*	*-1.45*	*-1.49*	*-0.71*	*0.11*	*0.77*	*1.00*	*1.16*
	s b	*29.77*	*29.92*	*29.89*	*29.74*	*29.56*	*24.92*	*23.11*	*21.21*	*19.71*	*19.19*	*18.82*
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*

Crash Barrier	s t	*0.68*	*0.66*	*0.62*	*0.56*	*0.47*	*0.39*	*0.28*	*0.17*	*0.07*	*0.03*	*0.00*
	s b	*-1.46*	*-1.41*	*-1.32*	*-1.19*	*-1.01*	*-0.82*	*-0.61*	*-0.36*	*-0.14*	*-0.06*	*0.00*
Wearing Coat	s t	*0.91*	*0.88*	*0.82*	*0.74*	*0.63*	*0.51*	*0.38*	*0.22*	*0.09*	*0.04*	*0.00*
	s b	*-1.94*	*-1.88*	*-1.76*	*-1.58*	*-1.34*	*-1.09*	*-0.81*	*-0.48*	*-0.19*	*-0.08*	*0.00*
Resultant	s t	***8.56***	***8.26***	***7.74***	***6.94***	***5.88***	***4.73***	***4.21***	***3.52***	***2.82***	***2.54***	***2.39***
	s b	***12.52***	***13.30***	***14.42***	***15.99***	***18.10***	***15.81***	***16.79***	***18.13***	***19.53***	***20.10***	***20.38***

5) DL + PS 23 Cables (After All Losses) + 2 Lane SIDL + 2 Lane VLL (Accompanying) + Temperature Fall (Leading)

Load factors as Per Table 3.3 of IRC 6-2016

Loads	*Rare Combination*	*Frequent Combination*	*Quasi Permanent Combination*
Dead Load	1	1	1
Superior Prestressing	1.1	1.1	1.1
Inferior Prestressing	0.9	0.9	0.9
Crash Barrier	1	1	1
Wearing Coat	1.2	1.2	1.2
VLL Leading	0.75	0.75	0
Temperature Fall	1	0.5	0.5
Differential Shrinkage	1	1	1

Minimum Allowable Compression = 0.5 Mpa (At joints)
Minimum Allowable Compression = 0 Mpa (At other locations)
Maximum Allowable Compression = 85 Mpa CL 3.1.6 NF P18 - 710
Maximum Allowable Compression = 54 Mpa (For Frequent and quasi permanent combination)

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***	
Node Numbers		***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***24.2***	
Prestress	s *t*	*1.11*	*0.96*	*0.74*	*0.10*	*-0.70*	*-1.46*	*-1.41*	*-1.43*	*-1.44*	*-1.45*	*-1.44*	*-1.44*	
	s *b*	*18.17*	*18.54*	*19.04*	*20.51*	*22.36*	*24.13*	*28.69*	*28.87*	*29.03*	*29.07*	*28.95*	*28.88*	
Dead Load	s *t*	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*	
	s *b*	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*	
Temperature	s *t*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	
	s *b*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	
Crash Barrier	s *t*	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*	
	s *b*	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*	
Wearing Coat	s *t*	*0.00*	*0.04*	*0.09*	*0.22*	*0.38*	*0.51*	*0.63*	*0.74*	*0.82*	*0.88*	*0.91*	*0.91*	
	s *b*	*0.00*	*-0.08*	*-0.19*	*-0.48*	*-0.81*	*-1.09*	*-1.34*	*-1.58*	*-1.76*	*-1.88*	*-1.94*	*-1.94*	
VLL	s *t*	*0.03*	*0.09*	*0.20*	*0.50*	*0.84*	*1.11*	*1.34*	*1.56*	*1.73*	*1.84*	*1.88*	*1.87*	
	s *b*	*-0.06*	*-0.18*	*-0.43*	*-1.06*	*-1.80*	*-2.37*	*-2.86*	*-3.34*	*-3.69*	*-3.92*	*-4.01*	*-4.01*	
Tension due to Torsion	s *t*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*	
	s *b*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*	
Differential Shrinkage	s *t*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	
	s *b*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	
Resultant (Superior Prestress)	s *t*	***2.56***	***2.37***	***2.75***	***3.64***	***4.57***	***5.27***	***6.61***	***7.86***	***8.80***	***9.43***	***9.80***	***9.80***	***Rare Combination***
	s *b*	***21.33***	***20.61***	***19.93***	***18.16***	***16.44***	***15.20***	***17.51***	***15.09***	***13.30***	***12.05***	***11.25***	***11.16***	
Resultant (Inferior Prestress)	s *t*	***2.34***	***2.18***	***2.60***	***3.62***	***4.71***	***5.56***	***6.89***	***8.14***	***9.08***	***9.72***	***10.08***	***10.09***	
	s *b*	***17.69***	***16.90***	***16.12***	***14.06***	***11.97***	***10.37***	***11.78***	***9.31***	***7.50***	***6.24***	***5.46***	***5.39***	
Resultant (Superior Prestress)	s *t*	***1.96***	***1.77***	***2.15***	***3.04***	***3.97***	***4.67***	***6.01***	***7.26***	***8.20***	***8.83***	***9.20***	***9.21***	***Frequent Combination***
	s *b*	***20.51***	***19.79***	***19.11***	***17.34***	***15.62***	***14.38***	***16.70***	***14.27***	***12.48***	***11.24***	***10.44***	***10.34***	
Resultant (Inferior Prestress)	s *t*	***1.74***	***1.58***	***2.01***	***3.02***	***4.11***	***4.96***	***6.29***	***7.54***	***8.48***	***9.12***	***9.48***	***9.49***	
	s *b*	***17.15***	***16.35***	***15.57***	***13.51***	***11.42***	***9.82***	***11.23***	***8.77***	***6.95***	***5.69***	***4.92***	***4.57***	
Resultant (Superior Prestress)	s *t*	***1.94***	***1.71***	***2.00***	***2.67***	***3.34***	***3.84***	***5.00***	***6.08***	***6.90***	***7.46***	***7.79***	***7.80***	***Quasi Permanent***
	s *b*	***20.83***	***20.20***	***19.70***	***18.41***	***17.24***	***16.43***	***19.11***	***17.05***	***15.53***	***14.45***	***13.72***	***13.35***	

Resultant (Inferior Prestress)	s t	***1.72***	***1.52***	***1.86***	***2.65***	***3.48***	***4.13***	***5.29***	***6.37***	***7.19***	***7.75***	***8.08***	***8.09***	***nent Combination***
	s b	***17.19***	***16.49***	***15.89***	***14.31***	***12.77***	***11.60***	***13.37***	***11.27***	***9.72***	***8.64***	***7.93***	***7.57***	

		13--13	***14--14***	***15--15***	***16--16***	***17--17***	***18--18***	***19--19***	***20--20***	***21--21***	***22--22***	***23--23***	
Distance (x)		***25.7***	***28.7***	***31.7***	***34.7***	***37.7***	***40.2***	***42.7***	***42.7***	***47.2***	***47.9***	***48.4***	
Prestress	s t	*-1.44*	*-1.45*	*-1.44*	*-1.43*	*-1.41*	*-1.46*	*-0.70*	*0.10*	*0.74*	*0.96*	*1.11*	
	s b	*28.95*	*29.07*	*29.03*	*28.87*	*28.69*	*24.13*	*22.36*	*20.51*	*19.04*	*18.54*	*18.17*	
Dead Load	s t	*7.07*	*6.83*	*6.40*	*5.76*	*4.90*	*4.03*	*2.98*	*1.77*	*0.68*	*0.27*	*0.03*	
	s b	*-15.11*	*-14.59*	*-13.68*	*-12.31*	*-10.48*	*-8.61*	*-6.38*	*-3.79*	*-1.45*	*-0.58*	*-0.06*	
Temperature	s t	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	
	s b	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	
Crash Barrier	s t	*0.68*	*0.66*	*0.62*	*0.56*	*0.47*	*0.39*	*0.28*	*0.17*	*0.07*	*0.03*	*0.00*	
	s b	*-1.46*	*-1.41*	*-1.32*	*-1.19*	*-1.01*	*-0.82*	*-0.61*	*-0.36*	*-0.14*	*-0.06*	*0.00*	
Wearing Coat	s t	*0.91*	*0.88*	*0.82*	*0.74*	*0.63*	*0.51*	*0.38*	*0.22*	*0.09*	*0.04*	*0.00*	
	s b	*-1.94*	*-1.88*	*-1.76*	*-1.58*	*-1.34*	*-1.09*	*-0.81*	*-0.48*	*-0.19*	*-0.08*	*0.00*	
VLL	s t	*1.88*	*1.84*	*1.73*	*1.56*	*1.34*	*1.11*	*0.84*	*0.50*	*0.20*	*0.09*	*0.03*	
	s b	*-4.01*	*-3.92*	*-3.69*	*-3.34*	*-2.86*	*-2.37*	*-1.80*	*-1.06*	*-0.43*	*-0.18*	*-0.06*	
Tension due to Torsion	s t	*-0.15*	*-0.18*	*-0.21*	*-0.23*	*-0.25*	*-0.27*	*-0.30*	*-0.34*	*-0.34*	*-0.37*	*0.00*	
	s b	*-0.15*	*-0.18*	*-0.21*	*-0.23*	*-0.25*	*-0.27*	*-0.30*	*-0.34*	*-0.34*	*-0.37*	*0.00*	
Differential Shrinkage	s t	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	
	s b	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	
Resultant (Superior Prestress)	s t	***9.80***	***9.43***	***8.80***	***7.86***	***6.61***	***5.27***	***4.57***	***3.64***	***2.75***	***2.37***	***2.56***	***Rare Combination***
	s b	***11.25***	***12.05***	***13.30***	***15.09***	***17.51***	***15.20***	***16.44***	***18.16***	***19.93***	***20.61***	***21.33***	
Resultant (Inferior Prestress)	s t	***10.08***	***9.72***	***9.08***	***8.14***	***6.89***	***5.56***	***4.71***	***3.62***	***2.60***	***2.18***	***2.34***	
	s b	***5.46***	***6.24***	***7.50***	***9.31***	***11.78***	***10.37***	***11.97***	***14.06***	***16.12***	***16.90***	***17.69***	
Resultant (Superior Prestress)	s t	***9.20***	***8.83***	***8.20***	***7.26***	***6.01***	***4.67***	***3.97***	***3.04***	***2.15***	***1.77***	***1.96***	***Frequent Combination***
	s b	***10.44***	***11.24***	***12.48***	***14.27***	***16.70***	***14.38***	***15.62***	***17.34***	***19.11***	***19.79***	***20.51***	
Resultant (Inferior Prestress)	s t	***9.48***	***9.12***	***8.48***	***7.54***	***6.29***	***4.96***	***4.11***	***3.02***	***2.01***	***1.58***	***1.74***	
	s b	***4.65***	***5.42***	***6.68***	***8.50***	***10.96***	***9.55***	***11.15***	***13.24***	***15.30***	***16.08***	***16.88***	

Resultant (Superior Prestress)	s t	***7.79***	***7.46***	***6.90***	***6.08***	***5.00***	***3.84***	***3.34***	***2.67***	***2.00***	***1.71***	***1.94***	***Quasi Permament Combination***
	s b	***13.45***	***14.18***	***15.26***	***16.78***	***18.84***	***16.15***	***16.97***	***18.14***	***19.43***	***19.92***	***20.56***	
Resultant (Inferior Prestress)	s t	***8.08***	***7.75***	***7.19***	***6.37***	***5.29***	***4.13***	***3.48***	***2.65***	***1.86***	***1.52***	***1.72***	
	s b	***7.66***	***8.37***	***9.45***	***11.00***	***13.10***	***11.33***	***12.50***	***14.04***	***15.62***	***16.22***	***16.92***	

6) DL + PS 23 Cables (After All Losses) + 2 Lane SIDL + 2 Lane VLL (Leading) + Temperature Fall (Accompanying)

Load factors as Per Table 3.3 of IRC 6-2016

Loads	*Rare Combination*	*Frequent Combination*	*Quasi Permanent Combination*
Dead Load	1	1	1
Superior Prestressing	1.1	1.1	1.1
Inferior Prestressing	0.9	0.9	0.9
Crash Barrier	1	1	1
Wearing Coat	1.2	1.2	1.2
VLL Leading	1	0.75	0
Temperature Fall	*0.6*	*0.5*	*0.5*
Differential Shrinkage	*1*	*1*	*1*

Minimum Allowable Compression = 0.5 Mpa (At joints)
Minimum Allowable Compression = 0 Mpa (At other locations)
Maximum Allowable Compression = 85 Mpa CL 3.1.6 NF P18 - 710
Maximum Allowable Compression = 54 Mpa (For Frequent and quasi permanent combination)

		1--1	***2--2***	***3--3***	***4--4***	***5--5***	***6--6***	***7--7***	***8--8***	***9--9***	***10--10***	***11--11***	***12--12***
Distance (x)		***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***24.2***
Prestress	s *t*	*1.11*	*0.96*	*0.74*	*0.10*	*-0.70*	*-1.46*	*-1.41*	*-1.43*	*-1.44*	*-1.45*	*-1.44*	*-1.44*
	s *b*	*18.17*	*18.54*	*19.04*	*20.51*	*22.36*	*24.13*	*28.69*	*28.87*	*29.03*	*29.07*	*28.95*	*28.88*
Dead Load	s *t*	*0.03*	*0.27*	*0.68*	*1.77*	*2.98*	*4.03*	*4.90*	*5.76*	*6.40*	*6.83*	*7.07*	*7.07*
	s *b*	*-0.06*	*-0.58*	*-1.45*	*-3.79*	*-6.38*	*-8.61*	*-10.48*	*-12.31*	*-13.68*	*-14.59*	*-15.11*	*-15.11*
Temperature Fall	s *t*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*	*1.20*
	s *b*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*	*1.64*
Crash Barrier	s *t*	*0.00*	*0.03*	*0.07*	*0.17*	*0.28*	*0.39*	*0.47*	*0.56*	*0.62*	*0.66*	*0.68*	*0.68*
	s *b*	*0.00*	*-0.06*	*-0.14*	*-0.36*	*-0.61*	*-0.82*	*-1.01*	*-1.19*	*-1.32*	*-1.41*	*-1.46*	*-1.46*
Wearing Coat	s *t*	*0.00*	*0.04*	*0.09*	*0.22*	*0.38*	*0.51*	*0.63*	*0.74*	*0.82*	*0.88*	*0.91*	*0.91*
	s *b*	*0.00*	*-0.08*	*-0.19*	*-0.48*	*-0.81*	*-1.09*	*-1.34*	*-1.58*	*-1.76*	*-1.88*	*-1.94*	*-1.94*
VLL	s *t*	*0.03*	*0.09*	*0.20*	*0.50*	*0.84*	*1.11*	*1.34*	*1.56*	*1.73*	*1.84*	*1.88*	*1.87*
	s *b*	*-0.06*	*-0.18*	*-0.43*	*-1.06*	*-1.80*	*-2.37*	*-2.86*	*-3.34*	*-3.69*	*-3.92*	*-4.01*	*-4.01*
Tension due to Torsion	s *t*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*
	s *b*	*0.00*	*-0.37*	*-0.34*	*-0.34*	*-0.30*	*-0.27*	*-0.25*	*-0.23*	*-0.21*	*-0.18*	*-0.15*	*-0.15*
Differential Shrinkage	s *t*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*	*0.09*
	s *b*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*	*-0.18*

Resultant (Superior Prestress)	s t	**2.09**	**1.92**	**2.32**	**3.29**	**4.30**	**5.06**	**6.46**	**7.77**	**8.75**	**9.41**	**9.79**	**9.79**	**Rare Combination**
	s b	**20.66**	**19.90**	**19.16**	**17.24**	**15.34**	**13.95**	**16.14**	**13.60**	**11.72**	**10.42**	**9.60**	**9.51**	
Resultant (Inferior Prestress)	s t	**1.87**	**1.72**	**2.18**	**3.27**	**4.44**	**5.36**	**6.74**	**8.05**	**9.04**	**9.70**	**10.07**	**10.08**	
	s b	**17.02**	**16.20**	**15.36**	**13.14**	**10.86**	**9.13**	**10.41**	**7.82**	**5.92**	**4.61**	**3.81**	**3.73**	
Resultant (Superior Prestress)	s t	**1.96**	**1.77**	**2.15**	**3.04**	**3.97**	**4.67**	**6.01**	**7.26**	**8.20**	**8.83**	**9.20**	**9.21**	**Frequent Combination**
	s b	**20.51**	**19.79**	**19.11**	**17.34**	**15.62**	**14.38**	**16.70**	**14.27**	**12.48**	**11.24**	**10.44**	**10.34**	
Resultant (Inferior Prestress)	s t	**1.74**	**1.58**	**2.01**	**3.02**	**4.11**	**4.96**	**6.29**	**7.54**	**8.48**	**9.12**	**9.48**	**9.49**	
	s b	**17.15**	**16.35**	**15.57**	**13.51**	**11.42**	**9.82**	**11.23**	**8.77**	**6.95**	**5.69**	**4.92**	**4.84**	
Resultant (Superior Prestress)	s t	**1.94**	**1.71**	**2.00**	**2.67**	**3.34**	**3.84**	**5.00**	**6.08**	**6.90**	**7.46**	**7.79**	**7.80**	**Quasi Permament Combination**
	s b	**20.83**	**20.20**	**19.70**	**18.41**	**17.24**	**16.43**	**19.11**	**17.05**	**15.53**	**14.45**	**13.72**	**13.62**	
Resultant (Inferior Prestress)	s t	**1.72**	**1.52**	**1.86**	**2.65**	**3.48**	**4.13**	**5.29**	**6.37**	**7.19**	**7.75**	**8.08**	**8.09**	
	s b	**17.19**	**16.49**	**15.89**	**14.31**	**12.77**	**11.60**	**13.37**	**11.27**	**9.72**	**8.64**	**7.93**	**7.85**	

		13--13	**14--14**	**15--15**	**16--16**	**17--17**	**18--18**	**19--19**	**20--20**	**21--21**	**22--22**	**23--23**
Distance (x)		**25.7**	**28.7**	**31.7**	**34.7**	**37.7**	**40.2**	**42.7**	**42.7**	**47.2**	**47.9**	**48.4**
Prestress	*s t*	-1.44	-1.45	-1.44	-1.43	-1.41	-1.46	-0.70	0.10	0.74	0.96	1.11
	s b	28.95	29.07	29.03	28.87	28.69	24.13	22.36	20.51	19.04	18.54	18.17
Dead Load	s t	7.07	6.83	6.40	5.76	4.90	4.03	2.98	1.77	0.68	0.27	0.03
	s b	-15.11	-14.59	-13.68	-12.31	-10.48	-8.61	-6.38	-3.79	-1.45	-0.58	-0.06
Temperature Fall	s t	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
	s b	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
Crash Barrier	s t	0.68	0.66	0.62	0.56	0.47	0.39	0.28	0.17	0.07	0.03	0.00
	s b	-1.46	-1.41	-1.32	-1.19	-1.01	-0.82	-0.61	-0.36	-0.14	-0.06	0.00
Wearing Coat	s t	0.91	0.88	0.82	0.74	0.63	0.51	0.38	0.22	0.09	0.04	0.00
	s b	-1.94	-1.88	-1.76	-1.58	-1.34	-1.09	-0.81	-0.48	-0.19	-0.08	0.00
VLL	s t	1.88	1.84	1.73	1.56	1.34	1.11	0.84	0.50	0.20	0.09	0.03
	s b	-4.01	-3.92	-3.69	-3.34	-2.86	-2.37	-1.80	-1.06	-0.43	-0.18	-0.06
Tension due to Torsion	s t	-0.15	-0.18	-0.21	-0.23	-0.25	-0.27	-0.30	-0.34	-0.34	-0.37	0.00
	s b	-0.15	-0.18	-0.21	-0.23	-0.25	-0.27	-0.30	-0.34	-0.34	-0.37	0.00
Differential Shrinkage	s t	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
	s b	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18	-0.18
Resultant (Superior Prestress)	s t	**9.79**	**9.41**	**8.75**	**7.77**	**6.46**	**5.06**	**4.30**	**3.29**	**2.32**	**1.92**	**2.09**	**Rare Combination**
	s b	**9.60**	**10.42**	**11.72**	**13.60**	**16.14**	**13.95**	**15.34**	**17.24**	**19.16**	**19.90**	**20.66**	
Resultant (Inferior Prestress)	s t	**10.07**	**9.70**	**9.04**	**8.05**	**6.74**	**5.36**	**4.44**	**3.27**	**2.18**	**1.72**	**1.87**	
	s b	**3.81**	**4.61**	**5.92**	**7.82**	**10.41**	**9.13**	**10.86**	**13.14**	**15.36**	**16.20**	**17.02**	
Resultant (Superior Prestress)	s t	**9.20**	**8.83**	**8.20**	**7.26**	**6.01**	**4.67**	**3.97**	**3.04**	**2.15**	**1.77**	**1.96**	**Frequent Combination**
	s b	**10.44**	**11.24**	**12.48**	**14.27**	**16.70**	**14.38**	**15.62**	**17.34**	**19.11**	**19.79**	**20.51**	
Resultant (Inferior Prestress)	s t	**9.48**	**9.12**	**8.48**	**7.54**	**6.29**	**4.96**	**4.11**	**3.02**	**2.01**	**1.58**	**1.74**	
	s b	**4.65**	**5.42**	**6.68**	**8.50**	**10.96**	**9.55**	**11.15**	**13.24**	**15.30**	**16.08**	**16.88**	
Resultant (Superior	s t	**7.79**	**7.46**	**6.90**	**6.08**	**5.00**	**3.84**	**3.34**	**2.67**	**2.00**	**1.71**	**1.94**	

(Superior Prestress)	s b	13.45	14.18	15.26	16.78	18.84	16.15	16.97	18.14	19.43	19.92	20.56	Quasi Permament Combination
Resultant (Inferior Prestress)	s t	8.08	7.75	7.19	6.37	5.29	4.13	3.48	2.65	1.86	1.52	1.72	
	s b	7.66	8.37	9.45	11.00	13.10	11.33	12.50	14.04	15.62	16.22	16.92	

8) Check for Deflection at Midspan (From Midas Civil)

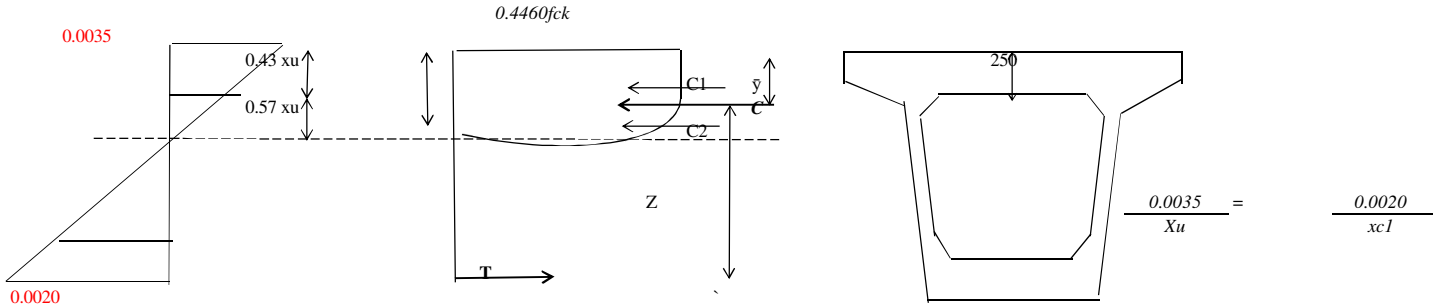
Loads	Deflections	Factor
Prestress =	85.60	1.00
Self weight =	-57.90	1.00
Crash Barrier =	-5.59	1.00
Wearing Coat =	-7.44	1.20
FPLL + VLL =	-14.38	0.75
Total =	**2.40** mm	

Permissible Deflection $= \frac{L}{800} = \frac{48400}{800} =$ **60.5** mm **Hence OK**

9) Ultimate moment capacity calculation

(i) Calculation of Neutral Axis Depth

Assuming Neutral axis lies within the top slab



$\frac{0.0035}{Xu} = \frac{0.0020}{xc1}$

Area of stress Block = 0.19 Xu + 0.17 Xu = 0.36 Xu

Moment of area about extream fibre = 0.15 xu^2

ȳ = 0.42 Xu

C = T *C*= 0.36*fck*b.xu fck= *M150*

b= *17200* ***mm***

bw= *600* ***mm***

Sections	1--1	2--2	3--3	4--4	5--5	6--6	7--7	8--8	9--9	10--10	12--12
Node Number	8	12	15	16	17	18	19	20	21	22	23
T = Prestessing Force (after friction and Slip loss)	78801.23	78896.04	79023.21	79406.55	79863.51	80400.03	81379.84	81860.45	82267.62	82272.53	81641.93
Xu=	84.84	84.94	85.08	85.49	85.99	86.56	87.62	88.14	88.57	88.58	87.90
0.42 Xu =	35.29	35.33	35.39	35.56	35.77	36.01	36.45	36.66	36.84	36.85	36.56

Sections	14--14	15--15	16--16	17--17	18--18	19--19	20--20	21--21	22--22	23--23
Node Number	24	25	26	27	28	29	30	31	34	38
T = Prestessing Force (after friction and Slip loss)	82272.53	82267.62	81860.45	81379.84	80400.03	79863.51	79406.55	79023.21	78896.04	78801.23
Xu=	88.58	88.57	88.14	87.62	86.56	85.99	85.49	85.08	84.94	84.84
85.08 Xu =	36.85	36.84	36.66	36.45	36.01	35.77	35.56	35.39	35.33	35.29

Depth of neutral axis = *87.90 Neutral axis lies web*

$$Xumax/d = \frac{\varepsilon_{cp} + \varepsilon_{cu}}{\varepsilon_{cp} \pm \varepsilon_{cu} + \varepsilon_{spu} - \varepsilon_{sp\infty}}$$

ε_{cu} , Ultimate strain in concrete at top = ***0.0035***

ε_{cp} , Strain in concrete at top due to prestress

$\varepsilon_{spα}$, Locked in strain in HTS immediately after anchorage

ε_{spu}, Ultimate strain at the C.G of the HTS

P_{final} , Pre-stressing force after all losses

εcp	=	*M / (Zt . Ep)*	=	***0.00003***	
εspu	=	*fp / Ep*	=	***0.00955***	
εspα	=	*Po / (Ap.Ep)*	=	***0.006843***	

Therefore, Xumax/d = ***0.566*** < ***0.032*** ***Under reinforced section***

Ultimate Moment of resistance, Mur : For neutral axis in web

= 0.36 fck.bw.(d-xu).(d - 0.42 xu) + 0.446 fck.(btf). Df. (d - 0.5 Df)

= *971639.9547 kNm* > *165402.7 kNm* OK

10) Check for Ultimate Shear **As per IRC 112-2020 (Cl:10.3.2)**

Ultimate Shear Check due to external loads:

	Section at	*Support*	*1st Junction*	*2nd Junction*	*3rd Junction*	*4th Junction*	*5th Junction*	*6th Junction*	*7th Junction*	*8th Junction*	*9th Junction*	*10th Junction*	*L/2*
	Distance from support	***0***	***0.5***	***1.2***	***3.2***	***5.7***	***8.2***	***10.7***	***13.7***	***16.7***	***19.7***	***22.7***	***22.7***
Combination 1 :- (DL + SIDL + WC + 4 Lane VLL) - Shear Due to Prestress													
(as per Cl:10.3.2 (5) of IRC 112)			**Factored**										
	Dead Load (kN)	7901.82	7724.81	7476.98	6768.90	5883.81	4991.18	4170.70	3245.28	2319.85	1394.43	469.00	6.29
	CB (kN)	738.34	723.09	701.73	640.71	564.44	488.16	411.89	320.36	228.83	137.30	45.77	0.00
	WC (kN)	1270.50	1244.25	1207.50	1102.50	971.25	840.00	708.75	551.25	393.75	236.25	78.75	0.00
	FPLL (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	VLL (kN)	2489.46	2489.46	2297.64	2265.57	2021.09	1844.19	1700.43	1556.69	1403.13	1193.42	981.68	981.68
	Shear due to prestress (kN)	3889.90	3753.40	3509.80	2901.50	2161.30	2830.90	3850.00	0.00	0.00	0.00	0.00	0.00
	Special Vehicle (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (kN)	8510.22	8428.21	8174.05	7876.18	7279.28	5332.63	3141.77	5673.57	4345.56	2961.39	1575.19	987.97
	V_{ED} (kN)=	**8510.22**	**8428.21**	**8174.05**	**7876.18**	**7279.28**	**5332.63**	**3141.77**	**5673.57**	**4345.56**	**2961.39**	**1575.19**	**987.97**
Shear per Outer Web			**Factored**										
	Dead Load (kN)	2607.60	2549.19	2467.40	2233.74	1941.66	1647.09	1376.33	1070.94	765.55	460.16	154.77	2.08
	CB (kN)	243.65	238.62	231.57	211.43	186.26	161.09	135.92	105.72	75.51	45.31	15.10	0.00
	WC (kN)	419.27	410.60	398.48	363.83	320.51	277.20	233.89	181.91	129.94	77.96	25.99	0.00
	FPLL (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	VLL (kN)	821.52	821.52	758.22	747.64	666.96	608.58	561.14	513.71	463.03	393.83	323.95	323.95
	Shear due to prestress (kN)	777.98	750.68	701.96	580.30	432.26	566.18	770.00	0.00	0.00	0.00	0.00	0.00
	Special Vehicle (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (kN)	3314.06	3269.25	3153.71	2976.33	2683.13	2127.78	1537.28	1872.28	1434.03	977.26	519.81	326.03
	V_{ED} (kN)=	**3314.06**	**3269.25**	**3153.71**	**2976.33**	**2683.13**	**2127.78**	**1537.28**	**1872.28**	**1434.03**	**977.26**	**519.81**	**326.03**
Shear per Inner Web			**Factored**										
	Dead Load (kN)	2607.60	2549.19	2467.40	2233.74	1941.66	1647.09	1376.33	1070.94	765.55	460.16	154.77	2.08
	CB (kN)	243.65	238.62	231.57	211.43	186.26	161.09	135.92	105.72	75.51	45.31	15.10	0.00
	WC (kN)	419.27	410.60	398.48	363.83	320.51	277.20	233.89	181.91	129.94	77.96	25.99	0.00
	FPLL (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	VLL (kN)	821.52	821.52	758.22	747.64	666.96	608.58	561.14	513.71	463.03	393.83	323.95	323.95
	VLL with congestion factor (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Shear due to prestress (kN)	1555.96	1501.36	1403.92	1160.60	864.52	1132.36	1540.00	0.00	0.00	0.00	0.00	0.00
	Special Vehicle (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total (kN)	2536.08	2518.57	2451.75	2396.03	2250.87	1561.60	767.28	1872.28	1434.03	977.26	519.81	326.03
	VED (kN)=	**2536.08**	**2518.57**	**2451.75**	**2396.03**	**2250.87**	**1561.60**	**767.28**	**1872.28**	**1434.03**	**977.26**	**519.81**	**326.03**
Shear per Web			**Factored**										
	Dead Load (kN)	2607.60	2549.19	2467.40	2233.74	1941.66	1647.09	1376.33	1070.94	765.55	460.16	154.77	2.08
	Rear Trolley (kN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Shear due to prestress (kN)	972.48	938.35	877.45	725.38	540.33	707.73	962.50	0.00	0.00	0.00	0.00	0.00
	Total (kN)	1635.13	1610.84	1589.95	1508.36	1401.33	939.36	413.83	1070.94	765.55	460.16	154.77	2.08
	VED (kN)=	**1635.13**	**1610.84**	**1589.95**	**1508.36**	**1401.33**	**939.36**	**413.83**	**1070.94**	**765.55**	**460.16**	**154.77**	**2.08**

Combination 1 :- (DL + SIDL + WC + 3 Lane VLL/SPL VLL) - Shear Due to Prestress

Shear due to Torsion (As per Cl:10.5.2 of IRC 112)

According to IRC:112-2020, CL:10.5.2.1 (1) & EN 1992-1-1 2004 CL 6.3.2, to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)													
f_{ck} = characteristic	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	Mpa
f_{cd} = Design values of Compressive Strength	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	Mpa
Torsional Moment in kN-m = TED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	kNm

u = perimeter	0.0	0.0	0.0	0.0	0.0	0.0	0.0						m
Ac = Area of C/s	0.0	0.0	0	0.0	0.0	0	0.0						mm^2
teff,i = A/u	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	mm
Ak = Area within cl of walls =	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	mm^2

Calculation of Ak and perimeter

	End section	Running section
Bottom Length (mm) =	5253.83	5253.83
Web length (mm) =	5673.27	5673.27
Top Length (mm) =	15452.04	15452.04
Area (Ak) =	15953248	15953248
Perimeter =	17063.57	17063.57

5673 2712

d	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	mm
$\tau_{t,i}$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Mpa
$V_{Ed,i}$	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	kN
Total Design shear Force= $V_{Ed} + V_{Ed,i}$	**2978.4**	**2924.1**	**2861.0**	**2659.1**	**2401.6**	**1787.9**	**1122.9**	**1622.6**	**1159.9**	**697.2**	**234.5**	**3.1**	kN

Combination 1 :- (DL + SIDL + WC + 4 Lane VLL/SPL VLL) - Shear Due to Prestress

Shear due to Torsion (As per Cl:10.5.2 of IRC 112)

According to IRC:112-2020, Cl:10.5.2.1 (1) & EN 1992-1-1 2004 CL 6.3.2, to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)

f_{ck} = characteristic	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	Mpa
f_{cd} = Design values of Compressive	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	Mpa
Torsional Moment in kNm from TED	2053.80	2053.80	1895.55	1869.10	1667.40	1521.46	1402.85	1284.27	1157.58	984.57	809.88	809.88	kNm
teff,i = A/u	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	mm
Ak = Area within cl of walls =	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	mm^2

Calculation of Ak and perimeter

	End section	Running section
Area (Ak) =	15953248.37	15953248.37
Perimeter =	17063.57	17063.57

d	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	mm
$\tau_{t,i}$	0.069	0.069	0.064	0.063	0.056	0.051	0.047	0.043	0.039	0.033	0.027	0.027	Mpa
$V_{Ed,i}$	**174.6**	**174.6**	**161.1**	**158.9**	**141.7**	**129.3**	**119.2**	**109.2**	**98.4**	**83.7**	**68.8**	**68.8**	kN
Total Design shear Force= $V_{Ed} + V_{Ed,i}$	**3488.6**	**3443.8**	**3314.8**	**3135.2**	**2824.9**	**2257.1**	**1656.5**	**1981.4**	**1532.4**	**1060.9**	**588.7**	**394.9**	kN

Maximum Shear Per Web

Total Design shear Force in Inner web =	2536.1	2518.6	2451.7	2396.0	2250.9	1561.6	767.3	1872.3	1434.0	977.3	519.8	kN
Total Design shear Force in Outer web =	3488.6	3443.8	3314.8	3135.2	2824.9	2257.1	1656.5	1981.4	1532.4	1060.9	588.7	kN

10.1) Shear Capacity per Web

		Outer Webs	Inner Web	
Section Web Width	b_w	**300**	**300**	mm
Section Web Depth	hw	**1724**	**2275**	mm
Effective Section Depth	d	1508.5	1990.625	mm
	z	1357.65	1791.5625	mm
Axial Force in the cross-section	N_{Ed}	**76065**	**76065**	kN
Design Shear Force	V_{Ed}	**3488.6**	**2536.1**	kN
Section 6.2.1.2	$\gamma_{cf}.\gamma_E$	**1.5**	**1.5**	
Elastic Modulus	E_c	**47270**	**47270**	MPa
Characteristic compressive strength	f_{ck}	**150**	**150**	MPa
Inclination of principal compression strut w.r.t. CG Longitudinal Axis of the section	θ	**30**	**30**	degrees

$\sigma_{cp} = N_{Ed} / A_c$

$$k = 1 + 3 \cdot \frac{\sigma_{cp}}{f_{ck}}$$

UHPFRC Contribution, $V_{Rd,c}$

Area of cross-section of UHPFRC	A_c	9558030	9558030	mm^2
Equation 6.203	σ_{cp}	7.96	7.96	MPa
Equation 6.202	k	1.16	1.16	
Equation 6.205	$V_{Rd,c}$	**925**	**1221**	**kN**

$$V_{Rd,c} = \frac{0.24}{\gamma_{cf}\gamma_E} k f_{ck}^{1/2} b_w z$$

Shear Rebar Contribution, $V_{Rd,s}$

Spacing	s	**100**	**100**	mm
Rebar Dia	φ	**0**	**0**	mm
Number of legs	N_{legs}	**1**	**1**	
C/S Area of shear reinforcement	A_{sw}	0.0	0.0	mm^2

Design elastic limit of shear rebar	$f_{y,wd}$	435	435	MPa
Angle of Inclination of Stirrups on long. Axis	α	90	**90**	degrees
Equation 6.208	$V_{Rd,s}$	**0**	**0**	**kN**

$$V_{Rd,s} = \frac{A_{sw}}{S} z f_{ywd} (\cot\theta + \cot\alpha)\sin\alpha$$

Fibre Contribution

C/S Area of section	A_{fv} = bw x z	407295	537468.75	mm^2
Orientation factor associated with local effects	K_{local}	1.75	1.75	NF P18-470 UHPC
Orientation factor associated with global effects	K_{global}	1.25	1.25	NF P18-470 UHPC
Characterstic post-cracking tensile strength	$f_{ctfk}/K.\Upsilon_{cf}$	**6.15**	**6.15**	MPa
Characteristic value of the tensile yield strength	$f_{ctk,el}/\Upsilon_{cf}$	**6.15**	**6.15**	MPa
Partial coefficient relating to the tensioned UHPC	γ_{cf}	1.3	1.3	
Maximum crack width	w	0.3	0.3	mm
Post cracking along shear crack of inclination θ	$\sigma_{Rd,f}$	6.15	6.15	MPa
Equation 6.209	$V_{Rd,f}$	4339	5725	kN

$$V_{Rdf} = A_{fv}\sigma_{Rdf}\cot\theta$$

Shear Strength= UHPFRC + Rebar + Fibre

		1775		
Shear Strength	V_{Rd}	**5264**	**6946**	**kN**
	V_{Ed}	**3489**	**2536**	**kN**
		OK	**OK**	

Shear Resistance Limitation

	αcc	0.85		
	Υ_c	1.5		
	Factor 1	1.73		
	Factor 2	4.00		
	Factor 3	0.58		
	$V_{Rd,max}$	**8652**	**kN**	
	$V_{Rd,Total}$	**8652**	kN	
D/C Ratio	$V_{Ed}/V_{Rd,Total}$	**0.403**		

$$V_{Rd,max} = 2.3\frac{\alpha_{cc}}{\gamma_C} b_w z f_{ck}^{2/3}\left[\frac{V_{Rd,s}(\cot\theta+\cot\alpha)}{(1+\cot^2\theta)} + V_{Rd,f}\tan\theta\right]\cdot\left[\frac{1}{V_{Rd,s}+V_{Rd,f}}\right]$$

Longitudinal tensile force due to strut action

	Factor 4	1.15	
	Factor 5	1.73	
Additional longitudinal tensile force (Eq 6.218)	ΔF_{td}	**2014**	**kN**

$$\Delta F_{td} = 0.5\ V_{Ed}\ [V_{Rd,f}\ (\cot\theta - \tan\theta) + V_{Rd,s}\ (\cot\theta - \cot\alpha)]\ /\ (V_{Rd,s} + V_{Rd,f})\ \geq 0$$

Resistance to Shear Buckling (As per cl. 509.4.2)

Shear resistance to Web buckling shall be verified,

if, d/t_w $> 67\varepsilon$ for a web without stiffeners

$\varepsilon = \sqrt{250/fy} =$ 1.715

$67\varepsilon =$ 114.904

$d/t_w =$ 13.560

Verification of Shear Buckling Not Required

$K_v =$ 5.35 When transverse stiffners are provided only at supports

$V_n = V_{cr}$

Vcr= Shear Force corresponding to Web buckling

τ_{cre} = Elastic Critical Shear Stress of the Web

$$\tau_{cre} = \frac{K_v \pi^2 E}{12(1-\mu^2)(d/t_w)^2}$$

$\tau_{cre} =$ 1178.33 N/mm^2

Non Dimensional Web Slenderness ratio for shear buckling stress(λw)

$\lambda_w = \sqrt{f_{yw}/(\sqrt{3} * \tau_{cre})}$

$\lambda_w =$ 0.20

Vcr= Av x τ_b

$\tau_b =$ $f_{yw}/\sqrt{3}$ if $\lambda_w \leq 0.8$

$(1-0.8(\lambda_w-0.8))*f_{yw}/\sqrt{3}$ if $0.8 < \lambda_w < 1.2$

$f_{yw}/(\sqrt{3}\lambda_w^2)$ if $\lambda_w \geq 1.2$

Hence, $\tau_b =$ 49.07 N/mm^2

$V_{cr} =$ **19987.91** kN > **3488.63** kN

Hence OK

Combination 1 :- (DL + SIDL + WC + 4 Lane VLL/SPL VLL) - Shear Due to Prestress

Shear due to Torsion (As per Cl:10.5.2 of IRC 112)

According to IRC:112-2011, Cl:10.5.2.1 (1) & EN 1992-1-1 2004 CL 6.3.2, to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)

Node Number	8	9	10	11	12	13	14	15	16	17	18	19	
f_{ck} = characteristic	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	Mpa
f_{cd} = Design values	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	67.0	Mpa
Torsional Moment in kNm — TED	1369.20	1369.20	1263.70	1246.06	1111.60	1014.30	935.24	856.18	771.72	656.38	539.92	539.92	kNm
teff,i = A/u	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	934.930	mm
Ak = Area within cl of walls	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	15953248	mm2

Calculation of Ak and perimeter

				End section	Running section								
		Area (Ak) =		15953248.37	15953248.37								
		Perimeter =		17063.57	17063.57								
d	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	2712.0	mm
$\tau_{t,i}$	0.046	0.046	0.042	0.042	0.037	0.034	0.031	0.029	0.026	0.022	0.018	0.018	Mpa
$V_{Ed,i}$	**116.4**	**116.4**	**107.4**	**105.9**	**94.5**	**86.2**	**79.5**	**72.8**	**65.6**	**55.8**	**45.9**	**45.9**	kN
Web Area	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**630147.5**	**mm^2**
Touv	**0.185**	**0.185**	**0.170**	**0.168**	**0.150**	**0.137**	**0.126**	**0.115**	**0.104**	**0.089**	**0.073**	**0.073**	*Mpa*
Tension due to torsion	**0.369**	**0.369**	**0.341**	**0.336**	**0.300**	**0.274**	**0.252**	**0.231**	**0.208**	**0.177**	**0.146**	**0.146**	*Mpa*

Tension due to torsion = **Sqrt(4 x Touv ^ 2)**

Preliminary Design of Single pier with pile foundation supporting 8.5m deck.

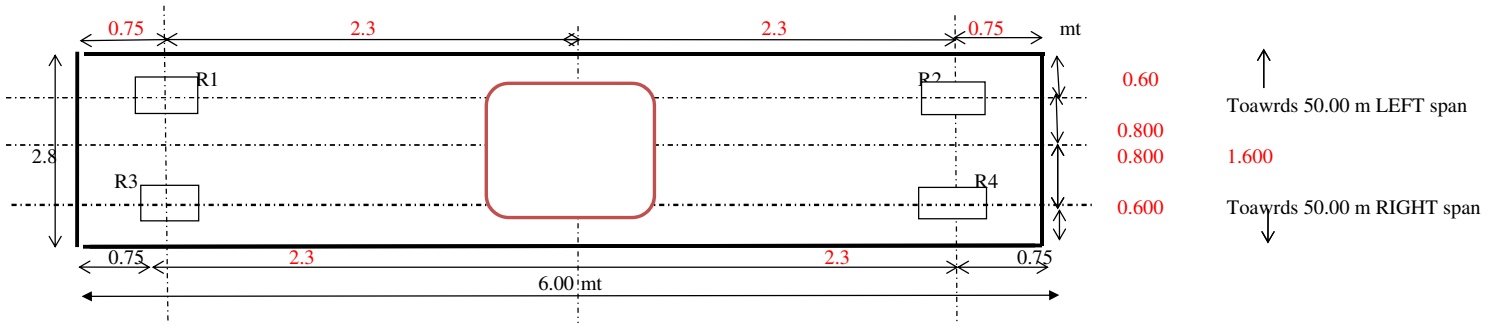
Design of Pier Substructure and Foundation for Piers between 50m and 50m Spans

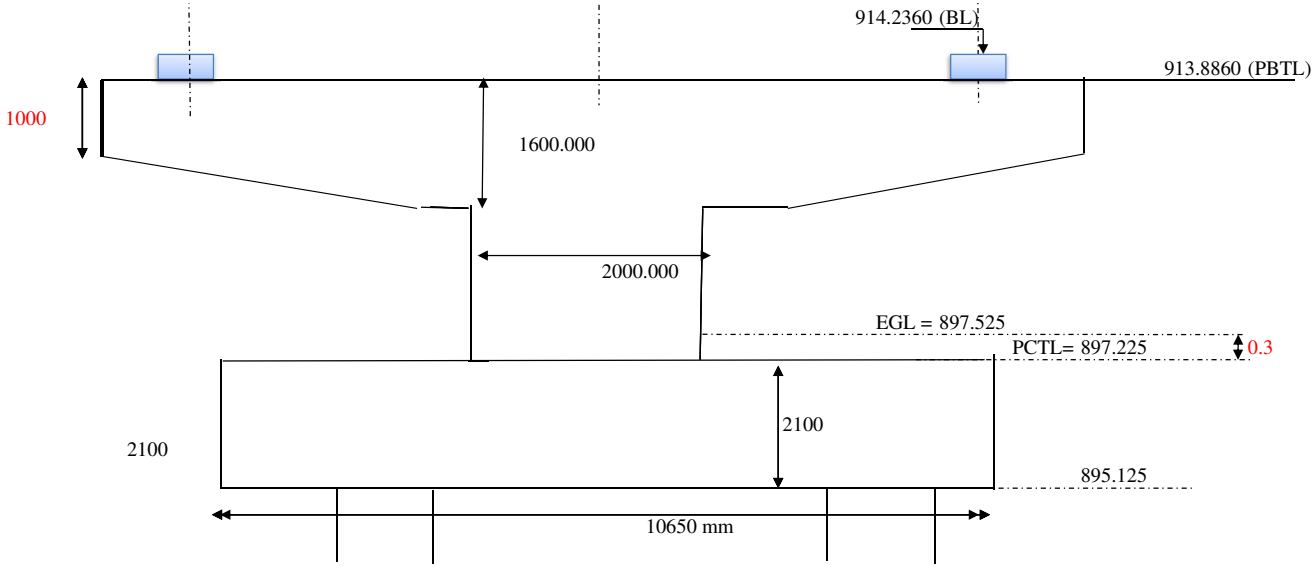
The Substructure is proposed with single Rectangular Pier with Pier Cap.The Foundation is Pile Foundation.The PTFE bearings are proposed on Pier Cap.
Pier Sustructure is analysed for load combinations as per IRC :IRC 6 and Designed following IRC 112-2011 codal provisions
This Design note presents design of Pier substructure and foundation for piers supporting 50m spans.

SCHEDULE OF LEVELS

Sl.No	PIER	FRL at edge of Median	EGL	Cross Slope	Superstructure depth +Wearing Coat	PBTL	PCTL	Total height of Pier (m)
1	P13	902.260	891.354	2.50%	2.764	899.1373	891.054	11.2060
2	P14	902.060	890.978	2.50%	2.764	898.9373	890.678	11.3820
3	P15	901.860	890.767	2.50%	2.764	898.7373	890.467	11.3930
4	P16	901.660	890.599	2.50%	2.764	898.5373	890.299	11.3610
6	P18	903.281	890.751	2.50%	2.764	900.1583	890.451	12.8300
7	P19	904.947	891.236	2.50%	2.764	901.8243	890.936	14.0110
8	P20	906.614	890.739	2.50%	2.764	903.4913	890.439	16.1750
9	P21	908.281	890.921	2.50%	2.764	905.1583	890.621	17.6600
10	P22	909.947	891.676	2.50%	2.764	906.8243	891.376	18.5710
11	P23	911.614	893.033	2.50%	2.764	908.4913	892.733	18.8810
12	P24	913.281	894.457	2.50%	2.764	910.1583	894.157	19.1240
13	P25	914.947	895.647	2.50%	2.764	911.8243	895.347	19.6000
14	P27	917.000	897.525	2.50%	2.764	913.8773	897.225	19.7750
15	P28	917.000	898.346	2.50%	2.764	913.8773	898.046	18.9540

Note: 1. From the above table, Pier P34 is critical, as the height of pier is more. Hence, design is carried out for P34, same details adopted for remaining piers in the group





1) GENERAL DATA FOR DESIGN

Finished Road Level	*FRL*	=	***917.000***	m	P26 Pier
Existing ground level	*EGL*	=	***897.525***	m	
Pier Bottom level	*PCTL*	=	***897.225***	m	
Pile Cap Bottom Level	*PCBL*	=	***895.125***	m	
Bearing Level	BL	=	***914.236***	m	
Height of super structure at centre of median (LEFT Span)	50.00 m span	SSD =	***2.712***	m	(Excluding wearing coat)
Height of Super Structure at centre of median (RIGHT Span)	50.00 m span	SSD =	***2.712***	m	(Excluding wearing coat)

DATA FOR PIER DESIGN

Overall Span of the Bridge (Left Span)	*50.00 m span*	=	*50000*	*mm*	
Effective Span of the Bridge (Left Span)	*50.00 m span*	=	*48400*	*mm*	
Overall Span of the Bridge (Right Span)	*50.00 m span*	=	*50000*	*mm*	
Effective Span of the Bridge (Right Span)	*50.00 m span*	=	*48400*	*mm*	
Overall Width of Deck		=	*17000*	*mm*	
Width of Medain		=	*1000*	*mm*	
Overall Heigth of Substructure (From Bearing Level to Pile Cap Top Level)		=	***17011.000***	*mm*	
Width of pier at top (long)		=	2200	*mm*	
Length of pier at top (trans)			2000	*mm*	
Pier Cap Width in Long Dir^{n}.		=	***2800.000***	*mm*	
Pier Cap Length in Trans Dir^{n}.		=	***6000.000***	*mm*	
Straight Depth of Pier Cap		=	***1500.0***	*mm*	PTFE Bearing

Size of bearing for (LEFT Span)	50.00 m span	=	**900**	**x 900**	**x 150**	**2**	*Nos*
Size of bearing for (RIGHT Span)	50.00 m span	=	**900**	**x 900**	**x 150**	**2**	*Nos*
Size of Pedestals for (LEFT span)	50.00 m span	=	**1200**	**x 1200**	**x 200**	**2**	*Nos*
Size of Pedestals for (RIGHT span)	50.00 m span	=	**1200**	**x 1200**	**x 200**	**2**	*Nos*

Total straight Height of Pier (From Pier Cap bottom to Pier Bottom Level) = **15161** *mm* *(Max.Height)*

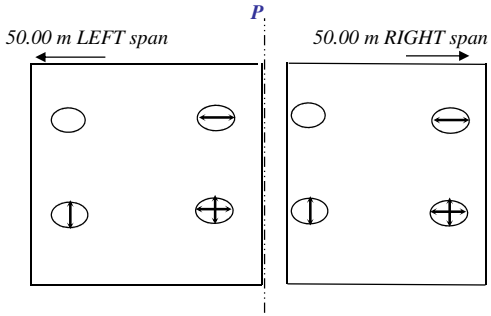
Width Of Pile Cap = **10650** *mm*

Length of Pile Cap = **5850** *mm*

Pile Cap Bottom Level = **895.125** *m*

Thickness of Pile Cap = **2100** *mm*

Thickness of Wearing coat = **52** *mm*



Constants

Density of concrete = **25** kN/m^3

Weight of wearing coat = **2** kN/m^2

Grade of Concrete for Pier Cap,Pier = **M - 60** *MPa.*

Grade of Concrete for Pile and Pile Cap = **M - 35** *MPa.*

Grade of Steel (substructure) = **Fe - 550** *MPa.*

AS PER IRC6:2016, TABLE B.2, PAGE NO 93, THE LOAD FACTORS IS AS UNDER

For Verification of Structural Strength

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*	*Seismic is Leading & VLL is accompanying*
1)	*SW =*	**1.35**	1.35	1.35
2)	*SIDL(W/o WC) =*	**1.35**	1.35	1.35
3)	*WC =*	**1.75**	1.75	1.75
4)	*VLL =*	**1.50**	1.15	0.2
5)	*BRAKING FORCE =*	**1.50**	*1.15*	0.2
6)	*WIND =*	**0.90**	*1.5*	-
7)	*Seismic =*	-	-	1.5

B.1) DEAD LOAD FROM SUPERSTRUCTURE(From STAAD)

Left Span 50,m ***Unfactored Loads***

	R1	*R2*
Self Weight	3338.00	3338.00
Crash Barrier+Median	282.20	282.20
WC	374.60	374.60
Total	***4069.72***	***4069.72***

Right Span- 50 m ***Unfactored Loads***

	R3	*R4*
DL	3333.00	3333.00
SIDL	282.20	282.20
WC	374.60	374.60
Total	***4064.72***	***4064.72***

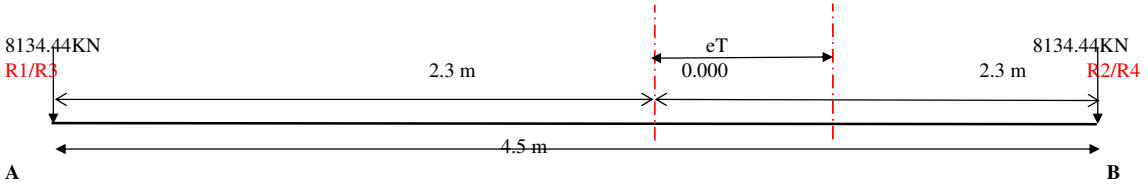
RESULTS FROM STAAD- 50.00 m LEFT span *Factored Loads*

	R1	R2
Self Weight	4506.30	4506.30
Crash Barrier+Median	380.97	380.97
WC	655.55	655.55
FPLL	0.00	0.00
TOTAL	**5542.82**	**5542.82**

RESULTS FROM STAAD- 50 m RIGHT span *Factored Loads*

	R3	R4
DL	4499.55	4499.55
SIDL	380.97	380.97
WC	655.55	655.55
FPLL	0.00	0.00
TOTAL	**5536.07**	**5536.07**

Cakculation of Transverse Moment due to Dead load



Cg of Loads from A	=		2.250	m
Cg of Loads from B	=		2.250	m
Eccentricity eT=	0.000	m		
MT=	0.00	KNm		(Unfactored)
MT=	0.00	KNm		(Factored)

Calcluation of Moment due to DL in Longitudinal Direction

50.00 e_L = 0.8 m

50.00 e_L = 0.800 m

Factored Longitudinal moment due dead load $M_{L\,(Factored)}$ = 8868.5 - 8857.71

= 10.8 kN-m

ML For Pier Cap Design=	5.40 (Factored)	ML For Pier Cap Design=	4.00 (Unfactored)
ML For Pier Design	10.80 (Factored)	ML For Pier Design	8.00 (Unfactored)

B.2) LIVE LOAD FROM SUPERSTRUCTURE

Following Vehicular Live loads are considered-

(i). 2 Class A vehicle

(ii). One 70RWL Vehicle

The variations of Live load combination is considered as per Table 2 of IRC 6-2017.

The reduction of longitudinal effect is considered as Cl:205 of IRC 6-2017

For 4 lanes Reduction in longitudinal effect = 20

Impact Factor : As per Cl 208 IRC : 6-2014
1) For Class A Vehicle,
2) For 70R Wheeled Vehicle

For 50.00m LEFT span	**L = 48.40 m**	For 50.00 m RIGHT span	**L = 48.40 m**
L= Effective	= 8.80% (Cl:208.2)	IF=4.5/(6+L)	= 8.80% (Cl:208.2)
Span	= 8.80% (Cl:208.2)	L= Effective Span	= 8.80% (Cl:208.2)

a) Vehicular Live Load from Staad pro.for 50.00 m LEFT Span (With impact Factor)

Eccentricity in longitudinal direction = 0.8 mt
For Four lanes 20 percent Reduction

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1113.80	1410.80	891.04	1128.64	**2019.68**	0.800	1615.74	0.265	534.60
4	70RWL+70RWL	949.50	1353.30	759.60	1082.64	**1842.24**	0.800	1473.79	0.395	726.84

b) Vehicular Live Load from Staad pro.for 50.00 m RIGHT Span (With impact Factor)

Summary of Reactions For Three Lanes: (From STADD Analysis)
For three lanes 20 percent Reduction
Eccentricity in longitudinal direction = 0.800 mt

Sl No	Vehicle case	R3(kN)	R4(kN)	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1113.80	1410.80	891.04	1128.64	**2019.68**	0.800	1615.74	0.265	534.60
4	70RWL+70RWL	949.50	1353.30	759.60	1082.64	**1842.24**	0.800	1473.79	0.395	726.84

c) Vehicular Live Load from Staad pro.for 50.00 m LEFT Span (Without impact Factor)

Eccentricity in longitudinal direction = 0.8 mt

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	**1841.95**	0.800	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	**1680.12**	0.800	1344.10	0.39	662.88

d) Vehicular Live Load from Staad pro.for 50.00 m LEFT Span (Without impact Factor)

Sl No	Vehicle case	R3(kN)	R4(kN)	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	**1841.95**	0.800	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	**1680.12**	0.800	1344.10	0.39	662.88

e) Vehicle on Both spans;
Summary of Reactions (From STADD Analysis)

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
2	2CA+2CA	626.00	352.10	604.50	340.00	500.80	281.68	483.60	272.00
4	70RWL+70RWL	689.50	253.70	659.50	242.70	551.60	202.96	527.60	194.16

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1538.08	0.800	21.50	0.63	969.12
1476.32	0.800	26.24	1.04	1534.68

f) Vehicle on Both span(Without impact Factor);

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
2	2CA+2CA	570.91	321.12	551.30	310.08	456.73	256.89	441.04	248.06
4	70RWL+70RWL	628.82	231.37	601.46	221.34	503.06	185.10	481.17	177.07

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1402.73	0.800	1122.18	0.63	883.84
1346.40	0.800	1077.12	1.04	1399.63

B.3 Braking Force (As per cl 211.2, IRC: 6- 2016)

Braking force is acts at 1.2 mt above road level

ML= HL x L.A

L.A = Lever Arm

Effective span (L) = 48.40 m

FRL = 917.000 m

1) For 50.00m LEFT span

Wearing coat = 0.052 m

Depth of super structure= 2.712 m

L.A = 2.764 + 1.2 = 3.96 m

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	ML=HL x L.A in kNm
2	2CA+2CA	1108.000	1108.000	110.800	55.400	166.200	658.817
4	70RWL+70RWL	1000.000	1000.000	200.000	50.000	250.000	991.000

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
13.612	6.806	83.100	41.55
20.475	10.238	125.000	62.50

2) For 50.00 m RIGHT span

Wearing coat = 0.052 m

Depth of super structure= 2.712 m

L.A = 2.764 + 1.2 = 3.96 m

Effective span (L) = 48.4 m

FRL = 917.000 m

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	ML=HL x L.A in kNm
2	2CA+2CA	1108	1108.00	110.80	55.40	166.20	658.82
4	70RWL+70RWL	1000	1000.00	200.00	50.00	250.00	991.00

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
13.61	6.81	83.10	41.55
20.48	10.24	125.00	62.50

Speciman calculation:

Additional axial load at bearing level= 110.8x(2.764+1.2)/48.4 9.075 kN

B.4 Friction Force (Normal Case): As per Cl.211.5.1.1 IRC:6-2016

Fixed Bearings : Fh - μ (Rg + Rq) or (Fh/2) + μ (Rg + Rq)

Fh = Applied Horizontal Force Due to Braking Effect

μ = Co-efficent Friction 0.05 For Surface between PTFE and Steel

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

Free Bearings : μ(Rg+Rq)

μ = Co-efficent Friction 0.05

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

For 50.00m LEFT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing	μ (Rg + Rq) per Bearing	μ (Rg) per Bearing
2	2CA+2CA	0.00	0.05	8139.44	2019.68	507.96	253.9780	203.486
4	70RWL+70RWL	0.00	0.05	8139.44	1842.24	499.08	249.5420	203.486
						507.96		

For 50.00 m RIGHT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg	Rq	F_h+μ (Rg + Rq) @ Fixed Bearing	F_h+ μ (Rg + Rq) per Bearing
2	2CA+2CA	166.200	0.050	8139.440	2019.680	674.16	337.078
4	70RWL+70RWL	250.000	0.050	8139.440	1842.240	749.08	374.542

B.5. Centrifugal Force Due to Curvature effect (As per Cl.212.2),IRC:6-2016

The centrifugal Force shall be considered to act at a height of 1.2mt above road level

$C=W V^2/127R$

Where

R=Radius of curve= 310 mt

V=speed in kmph= 0.00 kmph

w=Total Vehicular Live Load in kN=

Centri Fugal Force is acts at 1.2 mt above road level

MT= HT x L.A effective span = R4(kN) mt

L.A = Lever Arm

FRL = 917.000

Wearing coat = 0.0520 mt
Depth of super structure= 2.712 mt
L.A = 2.764 + 1.2 = 3.964 mt

Sl No	Vehicle case	Tot. Vehi Live Load in kN	Centrifugal Force	Total HT in kN	MT=HT x L.A in kNm	Add Axial load(kN)	HT/Trestle (kN)
2	2CA+2CA	2216.000	0.00	0.00	0.00	0.00	0.00
4	70RWL+70RWL	2000.000	0.00	0.00	0.00	0.00	0.00

B.6 Wind load calculation as per IRC 6:2016 Cl:209

Wind Speed at the Project Site 33 m/s
Avg Ht of the deck above EGL 20.475 m (ht of superstr+1m Crash barrier)

Type of Terrain — Since the Grade separator is inside the city with well developed Buildings.

	Terrain with obstructions	
	Height	Pz
Upto	10	0.1905
	15	0.2305
	20	0.2650
	20.475 m	0.268

Pressure as per table 0.268 kN/sqm FRL 917.000
Pressure as per table, corresponds to basic wind speed of 33 m/s
Design wind pressure =(wind speed at site^2/33^2) x Wind pressure corresponding to 33 m/sec
Deisgn wind pressure = 0.2682775x(33^2/33^2= 0.268 kN/sqm
Design Pressure Pz= **0.268** kN/sqm GL 897.525
Wind Force in Transverse direction = Pz X A1 X G X Cd
G = gust factor = 2.00
Cd = drag coeff =
1.1 for Slab bridges with b/d>10
1.5 for Box/single beam b/d 2
1.3 for Box/single beam b/d> 6
2.25 for 2 or more Box/ beam b/d 2
1.95 for 2 or more Box/ beam b/d > 6
2.20 for single plate girder
2(1+c/20d) for multiple plate girders
C= Centre to centre distance of adjacent girders = 2.25 m d =

Cd = 1.3 Corresponding to Box Girder

Wind on Superstructure :

For 50.00m LEFT span			**For 50.00 m RIGHT span**		
Wind Force in Transverse direction = Pz X A1 X G X Cd			Wind Force in Transverse direction = Pz X A1 X G X Cd		
Length of span from Centre to centre of Expansion Joint =		50 m	Length of span from Centre to centre of Expansion Joint =		50 m
Effective Span =		48.4 m	Effective Span =		L = 48.40 m
Width of Deck =		17 m	Width of Deck =		17 m
Superstructure Depth		2.764 m	Superstructure Depth		2.764 m
Total depth =(Superstucture Depth + Crash barrier height (1m))	SSD= 2.764 m CBD= 1.00m	3.764 m	Total depth	SSD = 2.764 m CBD= 1.000 m	3.764 m
Area of Superstructure	3.764 x 50.000	**188.200**	Area of Superstructure =	3.764 x 50.000	**188.200**
Force in Transverse direction = Pz X A1 X G X Cd			Force in Transverse direction = Pz X A1 X G X Cd		
FT = 0.268x188.2x2x1.3		**131.27** m^2	FT = 0.268x50x2x1.3		**131.27** m^2

MT Bearing Level due to 50.00 m span

L.A = 3.764 /2 = 1.882 m

MT Bearing Level due to 50.00 m span **= 247 KNm**

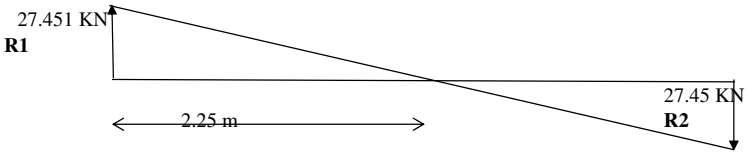
MT Bearing Level / span **= 124 KNm**

Add^{n} axial load = MT/(Eff.Bearing Spacing **123.53/4.5** **27.451** kN

Horizontal Force @ Bearing level per span = **65.637** kN

Force in long dir^{n} = 0.25 times FT = **32.818** kN

Add^{n} axial load = **32.82/48.4** = **1.3** kN



MT Bearing Level due to 50.00 m span

L.A = 3.764 /2 = 1.882 m

MT Bearing Level due to 50.00 m span **= 247 KNm**

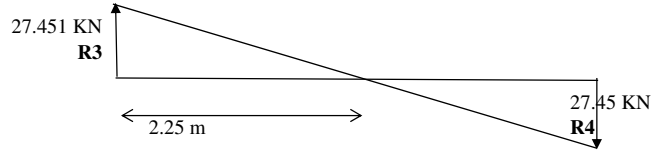
MT Bearing Level / span **= 124 KNm**

Add^{n} axial load = MT/(Eff.Bearing Spacing) = **123.53/4.5** **27.451** kN

Horizontal Force @ Bearing level per span= **65.637** kN

Force in long dir^{n} = 0.25 times FT = **32.818** kN

Add^{n} axial load = **32.82/48.4** = **1.28** kN



Wind Force on Vertical (+/-) **For 50.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Area of Superstructure (plan area) 50.0 x 17.0

A_3 = **850.000** m^2

CL = lift coeff = 0.750 for Slab/ box/ I girders and plate girders

Fv = 0.268x850x2x0.75 = **= 342.1KN**

Fv/ one side = = **= 171.0KN**

Vertical Force per Bearing = $\frac{171.027}{2}$ = **= 85.5KN**

Wind Force on Vertical (+/-) **For 50.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Superstructure (plan area) 50.0 x 17.0

A_3 = **850.0** m^2

CL = lift coeff = 0.750

Fv = 0.268x850x2x0.75 = **= 342.1KN** KN

Fv/ one side = **= 171.0KN**

cal Force per Bearing = $\frac{171.03}{2}$ = **= 85.5KN**

Wind on Live Load :

For 50.00m LEFT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.764 m

Ht of vehicle considerded above Crash barrier= =3-1 2.0 m

Area of Superstructure 2 x 50.0 **= 100.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.764 = 4.764 m

FT = 0.268x100x2x1.2 = **64.39KN**

MT Bearing Level due to 50.00 m span **64.39KN**

L.A = 4.764 m

MT Bearing Level due to 50.00 m span

MT= 64.387 x 4.764 **= 307 KNm**

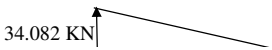
MT Bearing Level / span **= 153 KNm**

Add^{n} axial load = MT/(Eff.Bearing Spacing) = **153.37/4.5** **= 34.1KN**

Horizontal Force @ Bearing level per span = **= 32.2KN**

Force in long dir^{n} = 0.25 times FT **= 16.1KN**

Add^{n} axial load = **0.25x153.37/48.4** **= 0.8KN**



For 50.00 m RIGHT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.76 m

Ht of vehicle considerded above Crash barrier= 2.0 m

rea of Superstructure A1 = 2 x 50.0 **= 100.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.764 = 4.764 m

FT = 0.268x100x2x1.2 = **64.39KN**

MT Bearing Level due to 50.00 m span

L.A = 4.764 m

MT Bearing Level due to 50.00 m span

MT= 64.387 x 4.764 **= 307 KNm**

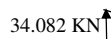
MT Bearing Level / span **= 153 KNm**

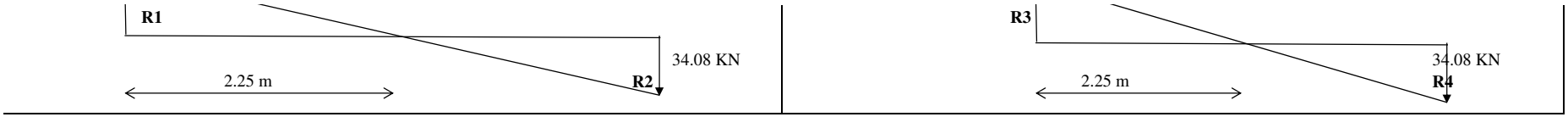
Add^{n} axial load = MT/(Eff.Bearing Spacing) = **153.37/4.5** **= 34.1KN**

Horizontal Force @ Bearing level per span = **= 32.19KN**

Force in long dir^{n} = 0.25 times FT **= 16.10KN**

Add^{n} axial load = **0.25x153.37/48.4** **= 0.79KN**





Summary of wind force at bearing level :

Sl No	Load case	HT (kN)	HT / Bearing (kN)	HL (kN)	HL / Bearing (kN)	Vertical Force(kN) / One side of span	Vertical Force(kN) / Bearing
1	Wind on loaded structure from 50.00m span (One side of LEFT span)	97.83	48.92	24.5	12.23	234.6	117.31
2	Wind on Unloaded structure from 50.00m span (One side of LEFT span)	65.64	32.82	16.4	8.20	199.8	99.88
3	Wind on loaded structure from 50.00m span (One side of RIGHT span)	97.83	48.915	24.5	12.229	234.6	117.314
4	Wind on Unloaded structure from 50.00m span (One side of RIGHT span)	65.64	32.818	16.4	8.205	199.8	99.877

DESIGN OF PIER CAP:

Distance from Face of Beam to cg of load — a = 1250.00 mm — No of Bearings on Cantilever Portion of Beam from LEFT — **50.00 m span** = 1

Thickness of corbel//Pier beam at face — h = 1600.000 mm

Effective depth of corbel/Pier beam — d' = 1492.000 mm — No of Bearings on Cantilever Portion of Beam from RIGHT — **50.00 m span** = 1

d = 1193.600 (0.8d')

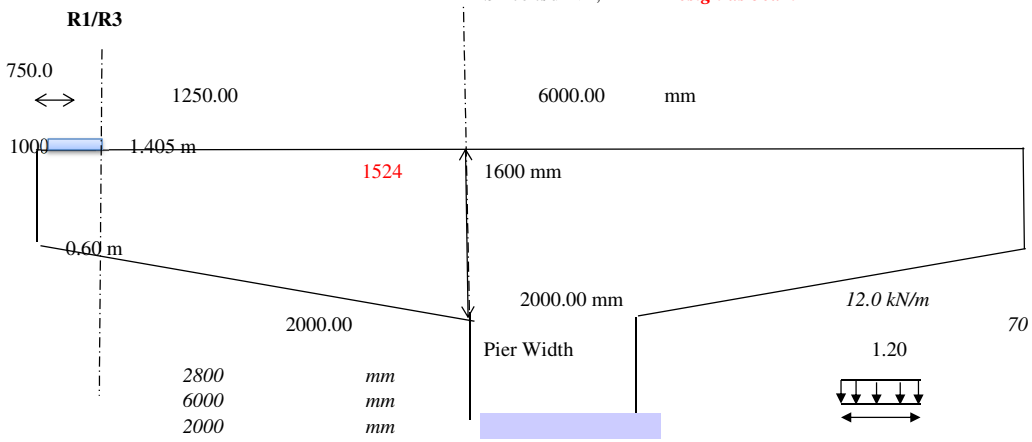
Thickness of Pier beam at end — S = 1000.000 mm

Eff. width of beam — b = 2800.000 mm

Checks

If a/d' <= 1.0 Design as a Corbel — actual a/d' = 0.838 — Vu/bd <= 0.15fc — 3.878 < 9.000 *safe*

Since a/d' < 1, ***Design as beam***



Lever Arms w.r.t face of pier	
L.A3=	1.250 m
L.A1=	1.250 m

Face of Pedestal-1

Pedestal Loading

Pier Beam width =	2800	mm
Total length of Pier beam =	6000	mm
Pier Width =	2000	mm

Summary of Forces on Pier Cap (Pier Beam) **(TABLE No -1)**

1) Forces on Pier Cap due to Dead load

	Loads for Factored Combination	Loads for Rare combination	Loads for Frequent combination

Type of Loads		P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Dead Load from Superstructure w.r.t to face of Pier	R1	5542.82	5.40	6928.53	4069.72	4.00	5087.15	4069.72	4.00	5087.15
	R3	5536.07	0.00	6920.09	4064.72	0.00	5080.90	4064.72	0.00	5080.90
Dead Load from superstructure w.r.t to face of Pedestal-@ (R1 +R5)	R1+R3	11078.89	5.40	6647.33	8134.44	4.00	4880.66	8134.44	4.00	4880.66

2) Forces on Pier Cap due to Vehicular Live load

Type of Loads		Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
		P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
VLL (One Span) w.r.t face of Pier	R1	1336.56	1069.25	*1670.70*	891.04	712.83	*1113.80*	668.28	534.62	*835.35*
	R3	1336.56	1069.25	*1670.70*	891.04	712.83	*1113.80*	668.28	534.62	*835.35*
VLL (One Span) w.r.t face of Pedestal@	R1	1336.56	1069.25	801.94	891.04	712.83	534.62	668.28	534.62	*400.97*
VLL (Both Span) w.r.t face of Pier	R1	1118.40	38.88	*1398.00*	745.60	25.92	*932.00*	559.20	19.44	*699.00*
	R3	1069.80	0.00	*1337.25*	713.20	0.00	*891.50*	534.90	0.00	*668.63*
VLL (Both Span) w.r.t face of Pedestal-(R1+R5)		2188.20	38.88	1312.92	745.60	25.92	447.36	559.20	19.44	335.52

3) Forces on Pier Cap due to Braking Force and Frictional Force

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Braking and Frictional Force at Bearing level (LEFT From 33.4m span)									
Braking force w.r.t face of Pier (R1)	15.36	742.89	19.20	10.24	495.26	12.80	7.68	371.44	9.60
Braking force w.r.t face of Pedestal@ (R1)	15.36	668.60	9.21	10.24	445.73	12.80	7.68	334.30	9.60
Braking and Frictional Force at Bearing level (RIGHT From 33.4m span)									
Braking force w.r.t face of Pier (R3)	15.36	1095.54	19.20	10.24	730.36	12.80	7.68	547.77	9.60
Braking force w.r.t face of Pedestal@ (R3)	15.36	985.98	9.21	10.24	657.32	6.14	7.68	492.99	4.61

4) Force due to Self Weight of Pier Beam and Pedestal

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Force due to Self Weight of Pier Beam									
Pier Beam w.r .t face of Pier	245.70		*226.76*	182.00		*167.97*	182.00		*182.00*
Pier Beam w.r .t face of Pedestal	153.41		*97.73*	113.64	0.00	*72.39*	113.64	0.00	*72.39*

Force due to Self Weight of Pedestal									
Pedestal w.r.t to face of Pier @ (R1+R3)	19.44		24.30	14.40	0.00	18.00	14.40	0.00	18.00
Pedestal w.r.t to face of Pedestal-@ (R1+R3)	19.44		11.66	14.40	0.00	8.64	14.40	0.00	8.64
5) Forces due to Wind on Pier Cap									
Type of Loads	**Loads for Factored Combination**			**Loads for Rare combination**			**Loads for Frequent combination**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***
Wind Forces on Super structure									
Wind on Super Structure w.r.t face of Pier @ (R1+R3)	49.41	113.18	*452.74*	32.94	75.46	*301.82*	27.45	62.88	251.52
Wind on Super Structure w.r.t face of Pedestal-@ (R1+R3)	49.41	107.42	*429.70*	32.94	71.62	*286.47*	27.45	59.68	238.72
Wind Forces on Live Load									
Wind on Live Load w.r.t face of Pier @ (R1+R3)	61.35	97.27	*389.06*	40.90	64.84	259.37	34.08	54.04	216.15
Wind on Live Load w.r.t face of Pedestal-@ (R1+R3)	61.35	94.44	*377.76*	40.90	62.96	251.84	34.08	52.47	209.87
Vertical force due to Wind									
Verticle wind load per Bearing w.r.t face of Pier @ (R1+R3)	153.92	0.00	*192.41*	102.62	0.00	128.27	85.51	0.00	106.89
Verticle wind load per Bearing w.r.t face of Pedestal-@ (R1+R3)	153.92	0.00	92.35	102.62	0.00	61.57	85.51	0.00	51.31

Load Combinations:
Comb:-1 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL One Span Condition)
Comb:-2 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL Both Span Condition)

Summary of Forces **(TABLE No -2)** **(Combination 1)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**12960.6**	**2380.63**	**16823.8**	**12868.3**	**2262.5**	**8467.7**
Rare Combination	**9408.57**	**1587.49**	**12170.09**	**9340.21**	**1508.73**	**6108.99**
Frequent Combination	**9153.84**	**1203.31**	**11787.56**	**9085.48**	**1143.76**	**5872.16**
Quasi Permanent Combination	**8330.84**	**4.00**	**10354.02**	**11251.74**	**5.40**	**6756.72**

Summary of Forces **(TABLE No -3)** **(Combination 2)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**13812.3**	**2093.15**	**17888.3**	**13720.0**	**1900.7**	**8978.7**
Rare Combination	**9976.33**	**900.58**	**12879.79**	**9194.77**	**821.82**	**6021.73**
Frequent Combination	**9579.66**	**688.12**	**12319.83**	**8976.40**	**628.58**	**5806.71**

Quasi Permanent Combination	**8330.84**	**4.00**	**10354.02**	**8262.48**	**4.00**	**4961.69**

1) DESIGN OF PIER CAP

Grade of concrete = M60
Grade of steel = Fe550

$Q = 0.133\ fck$ (for Fe 500)
$Q = 7.98\ N/mm2$

Design Moment = 17888.32 kNm (Combination 2) Table 3 — Clear Cover = 40 mm
Effective Depth Reqd "deff" = $\frac{M}{Q \times B}$ — Bar Dia = 32 mm

deff reqd: $= \sqrt{\frac{17888.32 \times 1000000}{7.98 \times 2800}}$

= 894.76 mm < 1524.00 mm O.K

deff provided = 1600 - 40 - 20.0 = 1524.00

Area of steel required (Ast) = (50*fck/fy)*(1-sqrt(1-(4.5*Mu/(fck*b*d^2))))*b*d/100

∴ Ast reqd = 27163.30 mm^2

Ast reqd for launching Girder case = 26469.36 mm^2

As1 = 804.2 mm^2

No of bars Reqd: = $\frac{27163.3}{804.2}$ = 33.77 — 40 Nos

Spacing of Bars = $\frac{2800}{40}$ = 70.00 mm

So provide 32 mm dia bars , 70 mm c/c spacing in 2 layer of 20 Nos
Ast Provided 32169.9 mm^2

Compression reinforcement 25 mm dia bars , of 20 Nos

Check for Serviceability Limit State

1) Stress Check Calculation As per IRC 112-2011 (Quasi Permanent Combination-Table No B.3 of IRC6-2016)

Width of pier beam =	b=	2800
Thickness of Beam (mm)	h =	1600
Dia of main Bar (mm)		32
Effective Depth (deff) mm		1524
Ast pro (mm2)		32170
Max Moment (kN-m)		13250.61
Es (N/mm^2)		200000
Ecm (N/mm^2)		16017
m = α = Es/Ecm		12.49
X_U (mm) =		533.18
L.A (mm) =		1346.27
Stress in Steel (N/mm2)		305.95
Permissible stress in steel		440
Check for stree in steel		Hence OK
Stress in Concrete (N/mm2)		13.19
Permissible stress in concrete		22

(Ref Table No-2 and 3)

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)
Stress in concrete= M/ (0.5.Xu.b.(L.A)

$X_u^2/2 = m\ Ast\ (d-X_u)$

a 1400.00
b 401689.13
c -612174236
Xu 1 = 533.18
Xu 2= -820.11

Check for stree in concrete		**Hence OK**

2) Crack Width Calculation As per IRC 112-2011 (Quasi Permanent Combination-Table No B.3 of IRC6-2016) **(As per IRC 112-2011, Cl:12.3.4)**

Dia of main Bar (mm)		32	
Spacing of Bars (mm)		140	
Max Moment (kN-m)		13250.61	(Ref Table No-2 and 3)
Ast pro As (mm^2)		32169.91	
C_{min} (mm)		40	
a_{cr} (mm)		73.64	
h (mm)		1600.00	
d (mm)		1524.00	
Es (N/mm^2)		200000	
Ecm (N/mm^2)		16017	
m = α = Es/Ecm		12.49	
Xu (mm)		533.18	
s_{sc} (N/mm^2)		305.95	
k_t =		0.5	
$f_{ct,eff}$ (N/mm^2)		3.3	
$A_{c,eff} = b*h_{c,eff}$ (mm^2)		532000.00	
$h_{c,eff}$ least of	2.5 (h - d)	190.0	
	(h - Xu/3)	1422.3	
	h / 2	800.0	
$r_{P,eff}$ =		0.0605	
$e_{sm} - e_{cm}$ =		0.0013	
		≥ 0.0009	
$e_{sm} - e_{cm}$ =		0.0013	
IRC 112-2011	k1 =	0.8	
	k2 =	0.5	
Spacing	5(c + F/2) =	280.00	
Case(i)	$S_{r,max}$ (mm)=	225.96	
Case(ii)	$S_{r,max}$ (mm) =	1386.86	
$S_{r,max}$ (mm) =		225.96	
W_k (mm) =		0.292	
Check for Crack Width		***Hence OK***	

3) Stress Check for Provided Steel (Rare Combination) (As per Table No B.3 of IRC6-2016)

Width of pier beam =	b=	2800	
Thickness of Beam (mm)	h =	1600	
Dia of main Bar (mm)		32	
Effective Depth (deff) mm		1524	
Ast pro (mm2)		32170	
Max Moment (kN-m)		13250.61	(Combination 2) Table 3
Es (N/mm^2)		200000	
Ecm (N/mm^2)		16017	

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)

Stress in concrete= M/ (0.5.Xu.b.(L.A)

a	1400.00
b	401689.13

$b X_u^2/2 = m Ast (d-X_u)$

m = α = Es/Ecm		12.49
X_U (mm) =		533.18
L.A (mm) =		1346.27
Stress in Steel (N/mm2)		305.95
Permissible stress in steel		479
Check for stree in steel		**Hence OK**
Stress in Concrete (N/mm2)		13.19
Permissible stress in concrete		29
Check for stree in concrete		**Hence OK**

c -612174236
Xu 1 = 533.18
Xu 2= -820.11

4) Deflection Check (By Freqent Combination-Table No B.3 of IRC6-2016)

For Cantiliver Slab *Deflection = $P*l^3$ / 3EI*

I = M.I = $bD^3/12$ = *9.55733E+11* mm2

Ec,eff = Ecm / (1+ ø)

Ecm = 37000 MPa (as per IRC-112, table-6.5) (Ref Table No-2 and 3)

P = 9579.66 *KN*

As per IRC:112-2011, table-6.9, for RH-80%, & 28 days age loading L = 1.25 *m*

ø 1= 1.7 for 150

ø 2= 1.5 for 600

ø = **1.31** for 1018 2Ac/u = 1018.18

Ec,eff = 16017.32

deflection = 0.41 mm

For cantiliver, as per IRC-112:2011, Cl:12.4.1(2)

δ = span / 300 4.17 *mm*

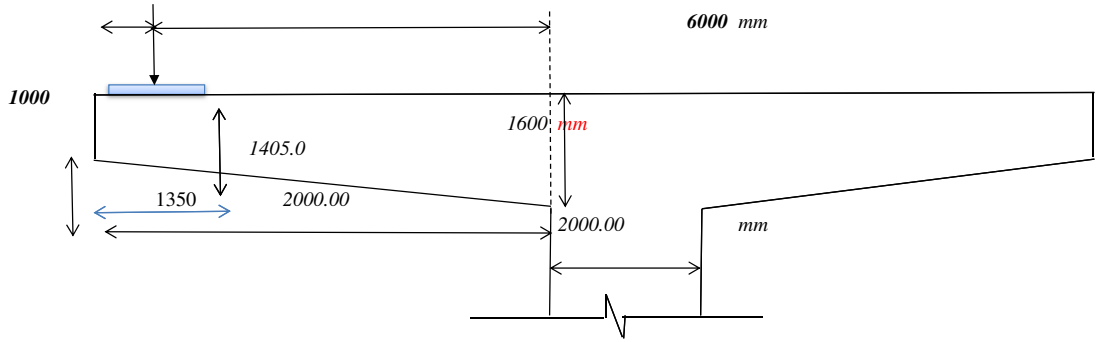
> *0.41* **Hence OK**

Check for Shear ***(As per Cl 10.3 of IRC 112-2011)***

pedestal size= 1.20 x 1.20 x 0.20 mt

R1/R3

750 *1250.0*



Check for Shear at the face of Pedestal @ (R1+R3)

Widh of Pier Cap (B) = 2800 mm

Depth at face of Pedestal (D)= 1405.0 mm

Effective depth at face of Pedestal (d)= 1297.0 mm

Total Shear force at face of Pedestal = *13720.0 KN* (Combination 2) Table 3

Moment at face of Pedestal (MT) = *8978.7 KNm* (Combination 2) Table 3

Effect of Torsion

According to IRC:112-2011, Cl:10.5.2.1 (1), to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)

$$\tau_{t,i} = \frac{T_{Ed}}{2A_k, t_{ef,i}}$$

T_{Ed}	=	2262.5	kN-m	(Combination 1) Table 2
A	=	3934000.0	mm2	
U	=	8410.0	mm	
$t_{ef,i}$	=	467.78	mm	
Ak	=	2185814.8	mm2	
Z_i	=	2800.0	mm	
$t_{t,i}$	=	1.1	N/mm2	

Design torsional shear force ($V_{Ed,i}$)

$V_{Ed,i}$ = $t_{t,i}t_{ef,i}Zi$

= 1.11 x 467.78 x 2800

= 1449113.09 N

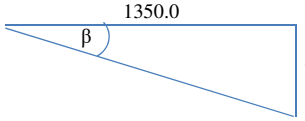
= 1449.11 kN

Total shear force (V_{NS}) = 13,719.98 + 1,449.11

= 15169.09 kN

Shear due to depth of Varying section

(From IS 456-2000 Cl:40.1.1) Shear due to Beams of Varying depth = $\frac{Mu \times \tan\beta}{d}$



β = 0.29

$\tan\beta = \frac{405.00}{1350.00}$ = 0.30

Mu = 8978.7 KNm (Combination 2) Table 3

(From IS 456-2000 $\frac{Mu \times \tan\beta}{d}$ = 2076.79 KN

Resultant Shear Force = VEd-Mu x tan β/d = 13092.30 kN

Check for $V_{Rd.c}$ *(As per Cl 10.3.2 of IRC 112-2011)*

The design shear resistance $V_{Rd.c} \geq V_{Ed.}$

The design shear resistance of the member without shear reinforcement $V_{Rd.c}$ is given by:

$$V_{Rd.c} = \left[0.12K(80\rho_1 . f_{ck})^{0.33} + 0.15\sigma_{cp} \right] b_w . d$$

Subject to a minimum of $v_{Rd.c} = (v_{min} + 0.15\sigma_{cp})\, b_w . d$ **Eq. 10.1**

$K = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ **where** d **is depth in millimeters.** **Eq. 10.2**

and $v_{min} = 0.031K^{3/2} f_{ck}^{1/2}$, **Eq. 10.3**

σ_{cp} **is limited to** $0.2 f_{cd}$ **(MPa) where** $\sigma_{cp} = N_{Ed} / A_c < 0.2 f_{cd}$ **(MPa)**

$\rho_1 = \frac{A_{sl}}{b_w . d} \leq 0.02$ **(Fig. 10.5)**

ρ1	=	0.009	
	=	0.009	
K	**=**	1.39	
N_{Ed}	**=**	0.00	KN
Ac	**=**	3934000.0	mm^2
σ_p	**=**	0.00	N/mm^2
$V_{Rd.c}$	**=**	**2850.68**	**kN**
V_{Ed}	=	13092.30	kN
$V_{Rd.c}$	<	V_{Ed}	

Hence Shear Reinforcement Required

As per A4.6.1, eq A4.5, IRC:112-2011,

V_{NS} = (ASW / S) * z * fywd * cot θ

f_{ywd} = 435.00 N/mm^2

Spacing (S) required = (ASW * z * fywd * cot θ / VNS

= 171 mm

Assuming

Hence proved **14 L** **Y - 20** **@ 140** **mm c/c**

Check for crushing of concrete (As per Cl 10.3.3.2 of IRC 112-2011)

At the face of Pedestal @ (R1+R3)

VRD.max = **αcw * bw * z * vi * fcd / (cotθ + tanθ)**

VRD.max = Crushing of compressive force for concrete

αcw =	1	
bw =	2800	mm
vi =	0.48	v=0.6*(1-fck/310)
fcd =	26.76	N/mm2
Z =	1167.300	mm

VRD.max = 21160.5 > 14262.2 kN

Hence Safe

Combined Check for Torsion and Shear (As per Cl 10.5.2 (4) of IRC 112-2011)

At the face of Pedestal @ (R1 +R3)

TRd.max = 2v * αcw * fcd * Ak * tef.i * sinθ * cosθ

TEd =	2262.49	kN-m	(Combination 1) Table 2
TRd.max =			
VEd =	13719.98	kN	(Combination 2) Table 3
VRd.max =	21160.51	kN	
v =	0.48		
TRd.max =			
Ak =	2185814.81	mm2	$(b-t_{ef,i}) \times (D-t_{ef,i})$
A=	3934000.00	mm2	
u =	8410.00	mm	
tef.i =	467.78	mm	
TRd.max =	13235.37	kN-m	

(TEd / TRd.max) + (VEd / VRd.max) ≤ 1.0 = 0.819

Hence Safe

Torsional Reinforcement (As per Cl 10.5.2 (5) of IRC 112-2011)

At the face of Pedestal @ (R1+R3)

Ak =	2.19	m2	
T_{ed} =	2262.49	kN-m	(Combination 1) Table 2
u_k =	6.54	m	
fyd =	478.26	N/mm2	

$$\Sigma asl = \frac{T_{Ed} * \cot\theta * uk}{2A_k * fyd}$$

$$\Sigma asl = \frac{2{,}262.49 \times \cot(1) \times 6.54}{2 \times 2.19 \times 47{,}82{,}60{,}869.57}$$

0.0071 m2

7075.93 mm2

However, same shall be compared w.r.t Launching girder erected case and reinforcement corresponding to maximum of 2 conditions shall be provided.

AsL required for Launching girder case = 30001.17

Required Longitudinal reinforcement will be distributed on 4 faces

Ast per face = 7500.292068

Hence Provide **Y - 25** **16 Nos**

Summary of Pier Cap Design:

1	*pier cap size =*	***6000 x***	***2800 x***	***1600 /***	***1000.0***	***mm***
2	*Grade of concrete =*		***M - 60***			
3	*Grade of steel =*		***Fe - 550***			
4	Tension Reinforcement in Transverse Direction =		**32**	**40 Nos**		
4a	Compression Reinforcement in Transverse Direction =		**Y 25**	**20 Nos**		
5	*Vertical stirrups =*		**14 L**	***- Y 20***	**140 c/c**	
6a	*Vertical stirrups =*		**0 L**	***- Y 0***	**140 c/c**	
6	*Torsional Reinforcement*		**Y 25**	**16 Nos**	**on either side of Pier beam in Transverse Direction**	

3) DESIGN OF PIER

Forces at Base of the pier and Foundation bottom:

i) Vehicle on one span for 50.00 m LEFT Span) (Without impact Factor)

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	1841.95	0.80	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	1680.12	0.80	1344.10	0.39	662.88

ii) Vehicle on one span for 50.00 m RIGHT Span) (Without impact Factor)

Sl No	Vehicle case	R3(kN)	R4(kN)	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
2	2CA+2CA	1015.79	1286.65	812.63	1029.32	1841.95	0.80	1473.56	0.26	487.56
4	70RWL+70RWL	865.94	1234.21	692.76	987.37	1680.12	0.80	1344.10	0.39	662.88

iii) Vehicle on Both Spans(without imact factor):

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)
2	2CA+2CA	570.91	321.12	551.30	310.08	500.80	281.68	483.60	272.00	1538.08
4	70RWL+70RWL	628.82	231.37	601.46	221.34	551.60	202.96	527.60	194.16	1476.32

eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
0.8	21.504	0.630	969.12
0.8	26.240	1.040	1534.68

iv A)Braking force from 50.00 m LEFT Span

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	**HL per Trestle (kN)**	**L.A For Pier Base**
2	2CA+2CA	1108.00	1108.00	110.80	55.40	166.20	83.10	17.01
4	70RWL+70RWL	1000.00	1000.00	200.00	50.00	250.00	125.00	17.01

ML @ pier base	**LA for Found^{n}**	**ML @ Found^{n}**	**Add Axial load(kN)**
1413.61	19.11	1588.12	29.207
2126.37	19.11	2388.87	43.933

iv B)Braking force from 50.00 m RIGHT Span

Sl No	**Vehicle case**	**1st,2nd and 3rdLANE in kN**	**3rd LANE in kN**	**1st & 2nd LANE(20%) in kN**	**3rd LANE(5%) in kN**	**Total HL in kN**	**HL per Trestle (kN)**	**L.A For Pier Base**
2	2CA+2CA	1108.00	1108.00	110.80	55.40	166.20	83.10	17.01
4	70RWL+70RWL	1000.00	1000.00	200.00	50.00	250.00	125.00	17.01

ML @ pier base	**LA for Foundn Bottom**	**ML @ Foundn base**	**Add Axial load(kN)**
1413.61	19.11	1588.12	29.207
2126.37	19.11	2388.87	43.933

iv A)Longitudinal Effect:(Frictional force) (From 33.4m LEFT span)

(one Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	**Vehicle case**	**Fh**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**
2	2CA+2CA	0.00	0.05	8139.44	2019.68	507.96
4	70RWL+70RWL	0.00	0.05	8139.44	1842.24	499.08
						406.97

L.A For Pier Base	**ML @ pier base**	**LA for Found^{n} Bottom**	**ML @ Found^{n} base**	**μ Rg**
17.01	8640.84	19.11	9707.55	406.972
17.01	8489.92	19.11	9537.99	406.972

B)Longitudinal Effect:(Frictional force) (From 33.4m LEFT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	**Vehicle case**	**Fh**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**L.A For Pier Base**	**ML @ pier base**	**LA for Found^{n} Bottom**	**ML @ Found^{n} base**
2	2CA+2CA	0.00	0.05	8139.44	713.62	442.65	17.01	7529.97	19.11	8459.54
4	70RWL+70RWL	0.00	0.05	8139.44	688.16	441.38	17.01	7508.31	19.11	8435.21

B)Longitudinal Effect:(Frictional force) (From 33.4m RIGHT span)

(One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing
2	2CA+2CA	166.20	0.05	8139.44	2019.68	674.16
4	70RWL+70RWL	250.00	0.05	8139.44	1842.24	749.08

L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base	μ Rg
17.01	11468.07	19.11	12883.80	406.972
17.01	12742.67	19.11	14315.74	406.972

C)Longitudinal Effect:(Frictional force) (From 33.4m RIGHT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing	L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base
3	2CA+2CA	166.20	0.05	8139.44	689.11	607.63	17.01	10336.35	19.11	11612.37
5	70RWL+70RWL	250.00	0.05	8139.44	658.25	689.88	17.01	11735.62	19.11	13184.38

v) SELF WEIGHT OF PIER AND PIER SUBSTRUCTURE:

B= 2.8

Pedastal size= 0.2880 m^3

No of pedastal= 4.0

Total sw of pedastal= 28.8 kN

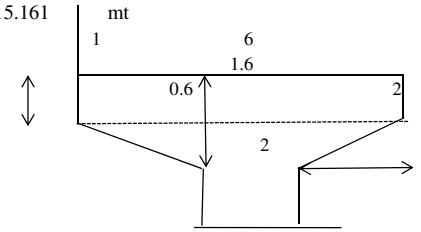
sw of pier beam = 588.0 kN

Area of pier = 4.40 m^2

sw of pier = **1667.7** kN

Total sw = ***2284.5*** kN

Height of pier= 15.161 mt



vi) Wind Force

Wind on Pier Beam :

Width of Pier Cap 2.80 *m* *(b)* *t/b = 2.14*

Height of Pier Cap 1.60 *m* *(h)* *h/b = 0.57*

Length of Pier Cap 6.00 *m* *(t)*

Cd 0.8

Force in Transverse direction = Pz X A1 X G X Cd

A1 = 2.80 *m X* 1.60 *m =* 4.48 *sqm*

Ft = 0.268 X 4.48 X 2 X 0.8

1.92 kN

Force in long dirn = 25% *of F transverse =* 0.5 *kN*

Wind on Pier :

Width of Pier	*2.2 m*	*(b)*	*t/b =*	*0.91*	
Height of Pier	*14.6610 m*	*(h)*	*h/b =*	*6.66*	
Length of Pier	*2 m*	*(t)*			
Cd value	*1.33*				

Force in Transverse direction = Pz X A1 X G X Cd

A1 = *2.20 m X* *14.661 m =* *32.2542 sqm*

Ft = *0.268* *X* *32.2542* *X* *2* *X* *1.3345*

23.1 kN

Force in long dirn = *25% of F transverse =* *5.8 kN*

vii) Summary of Wind Load

Wind Force due to DL@ Bearing level	*Lever Arm in mt*	*Transeverse dirction*	*longitudinal dirction*	
Wind force Horizontal due to 50.00 m Left span		*65.637*	*16.41*	
Wind force Horizontal due to 50.00 m Right span span		*65.637*	*16.41*	
Moment at base of pier due to 50.00 m Left span	*17.011*	*1116.55*	*279.14*	
Moment at base of pier due to 50.00 m Right span	*17.01*	*1116.55*	*279.14*	
Moment at base of foundation due to 50.00 m Left span	*19.11*	*1254.38*	*313.60*	
Moment at base of foundation due to 50.00 m Right span	*19.11*	*1254.38*	*313.60*	
Total Horizontal Wind force		*131.3*	*32.8*	*kN*
Total Moment at base of pier		*2233.1*	*558.3*	*kNm*
Total Moment at base of foundn	*19.111*	*2508.8*	*627.2*	*kNm*
Wind on pier Cap		***FT***	***FL***	
Wind force Horizontal		*1.9*	*0.5*	*kN*
Moment at base of pier	*15.961*	*30.7*	*7.7*	*kNm*
Moment at base of foundn	*18.061*	*34.7*	*8.7*	*kNm*
Wind on pier		***FT***	***FL***	
Wind force Horizontal	*m*	*23.1*	*5.8*	*kN*
Moment at base of pier	*7.830*	*180.8*	*45.2*	*kNm*
Moment at base of foundn	*9.930*	*229.3*	*57.3*	*kNm*
Total wind load on DL only		***FT***	***FL***	
Wind force Horizontal		*156.3*	*39.1*	*kN*
Moment at base of pier		*2444.6*	*611.2*	*kNm*
Moment at base of foundn		*2772.8*	*693.2*	*kNm*
Wind due to LL at bearing level		***FT***	***FL***	
Wind force Horizontal due to 50.00 m span		*32.2*	*8.05*	
Wind force Horizontal due to 50.00 m span		*32.2*	*8.05*	
Moment at base of pier due to 50.00 m span	*17.011*	*547.64*	*136.91*	
Moment at base of pier due to 50.00 m span	*17.011*	*547.64*	*136.91*	
Moment at base of foundation due to 50.00 m span	*19.111*	*615.25*	*153.81*	
Moment at base of foundation due to 50.00 m span	*19.111*	*615.25*	*153.81*	
Total Horizontal Wind force		*64.4*	*16.1*	
Total Moment at base of pier		*1095.3*	*273.8*	*kNm*
Total Moment at base of foundn		*1230.5*	*307.6*	*kNm*

Wind force Vertical in kN	*(From Both spans)*		*811.310*	*kN*

ix) Seismic Analysis of Pier Sub Structure:

The seismic analysis is carried out as per the IRC: 6 – 2016 (Cl:219).

Feq = Ah x (Dead Load + Appropriate live load)
Where,
Ah = Horizontal seismic co – efficient
AR = Z.I / 2.R x Sa / g

Z = zone factor =	*0.1*	***(Zone – II)***	(Table-16 of IRC 6-2016)	
R =	*2.5*	(Table-20 of IRC 6-2016)		
I =	*1.2*	(Table-19 of IRC 6-2016)		
Dead Load Rxn =			*16268.88*	***kN***
VLL Rxn =	*20%*	*1538.08*	*307.62*	***kN***
Total =			***16576.496***	***kN***

As Per IRC:6- 2016 *(Annexure-D)*
T=2√W/(1000F)
WL^3 / 3EI = *1.0*

W=	*13.049*	***kN***
T=	*2.254*	***Sec***
Sa /g =	*0.444*	

T = *2.25 sec*
Sa /g = 0.444

Ah = *0.1*1.2*0.44/(2*2.5)* ***0.011***

l = Height of pier = *17011* *mm*
Ecm = *16087.0* *N/mm^2*

$$I_{gr} = \frac{b \times d3}{12}$$

Igr = 1774666666667 *mm^4*
I_{eff} = *1.331E+12* *mm^4*
(0.75 x Igr)

Ecm = 37000 MPa (as per IRC-112, table-6.5)

As per IRC:112-2011, table-6.9, for RH-50%, & 28 days age loading

ø 1=	1.7	for	150
ø 2=	1.5	for	600
ø =	**1.30**	for	1048

Ec,eff = 16086.96 MPa 2Ac/u = 1047.62

i) Longitudinal direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Total Seismic load (Long-HL)**	
1	DL	16268.88	**173.21**	
2	Pier cap	700.00	7.45	
3	pedastals	28.80	0.31	
4	Pier	1667.71	17.76	

ii) Transeverse direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Trans-HT)**	
1	DL	16268.88	**173.21**	
2	Pier cap	700.00	**7.45**	
3	pedastals	28.80	**0.31**	
4	Pier	1667.71	**17.76**	

iii) Vertical direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Vertical-Vs)**	
1	DL	16268.88	**115.48**	
2	Pier cap	700.00	**4.97**	
3	pedastals	28.80	**0.20**	
4	Pier	1667.71	**11.84**	

Seismic in Longitudinal Direction due to 50.00 m span						**Total ML @ pier base**	**Total ML @ Pile Cap bottom**
Component	**HL**	LA w.r.to pier base	**ML @ pier base**	LA w.r.to pier base	**ML @ Pile Cap bottom x 1.35**		
DL	173.21	18.3670	3181.43	20.4670	4786.00	**3181.43**	**4786.0**
Pier cap	7.45	15.8610	118.21	17.9610	180.71	**118.21**	**180.7**
pedastals	0.31	16.7610	5.14	18.8610	7.81	**5.14**	**7.8**
Pier	17.76	7.5805	134.60	9.6805	232.05	**134.60**	**232.0**

Seismic Transverse Direction due to 50.00 m span						**Total MT @ pier base**	**Total MT @ Pile Cap bottom**
Component	**HT**	LA w.r.to pier base	**MT @ pier base**	LA w.r.to pier base	**MT @ Pile Cap bottom x 1.35**		
DL	173.21	18.367	3181.43	20.47	4786.00	**3181.43**	**4786.0**
Pier cap	7.45	15.861	118.21	17.96	180.71	**118.21**	**180.7**
pedastals	0.31	16.761	5.14	18.86	7.81	**5.14**	**7.8**
Pier	17.76	7.580	134.60	9.68	232.05	**134.60**	**232.0**

Note: ***1.35*** For design of foundation, the seismic loads should be taken as 1.35 times the forces transmitted to it by concrete substructure.(219.8 of IRC 6-2014)

iv) Vehicle on one span(Without impact Factor) Seismic case: for 50.00 m LEFT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
2	2CA+2CA	**354.560**	**0.000**	**3.775**	17.011	**64.22**	**97.51**
4	70RWL+70RWL	**320.000**	**0.000**	**3.407**	17.011	**57.96**	**132.58**

LA w.r.to Found^{n} Bottom	**MT (kNm) Pile Cap bottom (due to seismic) x 1.35**	**Total MT @ Pile Cap Base**	**ML due toVLL Eccentricity (kN-m)**
19.111	**97.39**	**194.91**	**294.71**
19.111	**87.90**	**220.48**	**268.82**

v) Vehicle on one span(Without impact Factor) Seismic case: for 50.00 m RIGHT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
2	2CA+2CA	**354.56**	**0.000**	**3.775**	17.011	**64.22**	**97.51**
4	70RWL+70RWL	**320.00**	**0.000**	**3.407**	17.011	**57.96**	**132.58**

LA w.r.to Found^{n} Bottom	**MT (kNm) Pile Cap bottom due to seismic x 1.35**	**Total MT @ Pile Cap Base**	**ML due to VLL Eccentricity (kN-m)**
19.111	**97.39**	**194.91**	**294.71**
19.111	**87.90**	**220.48**	**268.82**

vi) Vehicle on Both Span (without imact factor):

Sl No	**Vehicle case**	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	L Arm W.r t.pier base	**MT (kNm) pier base due to seismic**	**MT Due toVLL Eccentricity**
2	2CA+2CA	**354.56**	**0.000**	**3.77**	17.011	64.216	**193.82**
4	70RWL+70RWL	**320.00**	**0.000**	**3.41**	17.011	57.957	**306.94**

LA W.r t.Found Bottom	**MT (kNm) Pile Cap bottom due to seismic x 1.35**	**ML Due to VLL Eccentricity**
19.111	**97.39**	**4.301**
19.111	**87.90**	**5.248**

vi)Braking force(seismic case): 50.00 m LEFT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
2	2CA+2CA	1108.0	1108.0	221.6	55.4	219.6	4.54	**27.7**	17.01
4	70RWL+70RWL	1000.0	1000.0	200.0	50.0	198.2	4.10	**25.0**	17.01

LA at footing bottom	**ML @ Pier bottom**	**ML @ Pile Cap bottom**
19.111	**471.20**	**529.37**
19.111	**425.27**	**477.77**

v)Braking force(seismic case): 50.00 m RIGHT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
2	2CA+2CA	1108.0	1108.0	221.6	55.4	219.6	4.54	**27.7**	17.01

4	70RWL+70RWL	1000.0	1000.0	200.0	50.0	198.2	4.10	**25.0**	17.01

LA at footing bottom	**ML @ Pier bottom**	**ML @ Pile Cap bottom**
19.111	**471.20**	**529.37**
19.111	**425.27**	**477.77**

viA)Frictional (seismic case): 50.00 m LEFT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2014)

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
2	2CA+2CA	0.0	0.05	8139.4	403.9	**427.2**	**406.97**	17.011
4	70RWL+70RWL	0.0	0.05	8139.4	368.4	**425.4**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	**ML @ Pile Cap bottom**
7266.6	19.111	**8163.6**
7236.4	19.111	**8129.7**

B)Frictional force(seismic case): 50.00 m Left Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2014)

Sl No	Vehicle case	**Fh x 0.2**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
2	2CA+2CA	0.0	0.05	8139.4	713.6	**442.7**	**406.97**	17.011
4	70RWL+70RWL	0.0	0.05	8139.4	688.2	**441.4**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	**ML @ Pile Cap bottom**
7530.0	19.111	**8459.5**
7508.3	19.111	**8435.2**

C)Frictional force(seismic case): 50.00 m RIGHT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq / one side of span x 0.2**	**Fh+μ (Rg + Rq) @ Fixed Bearing**	**μ (Rg)**	L.A For Pier Base
2	2CA+2CA	33.2	0.05	8139.4	403.9	**460.4**	**406.97**	17.011
4	70RWL+70RWL	50.0	0.05	8139.4	368.4	**475.4**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	**ML @ Pile Cap bottom**
7832.0	19.111	**8798.9**
8086.9	19.111	**9085.3**

D)Frictional force(seismic case): 50.00 m RIGHT Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

(seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2014)

Sl No	Vehicle case	Fh x 0.2	μ	Rg / one side of span	Rq / one side of span x 0.2	Fh+μ (Rg + Rq) @ Fixed Bearing	μ (Rg)	L.A For Pier Base
2	2CA+2CA	33.2	0.05	8139.4	137.8	**447.1**	**406.97**	17.011
4	70RWL+70RWL	50.0	0.05	8139.4	131.6	**463.6**	**406.97**	17.011

ML @ pier base	LA w.r.to Pile CapBottom	ML @ Pile Cap bottom
7605.7	19.111	**8544.6**
7885.5	19.111	**8859.0**

DESIGN OF PIER:

A). PIER LOAD COMBINATIONS

C1 to C6 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF)*

C7 to C12 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)*

C13 to C18 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C18 to C24 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C25 = *DL+SW+WIND ON UNLOADED STURCTURE*

C26 = *Launching Girder Case*

The Pier section is designed as a circular section subjected to axial force and bending using SP-16, Design Aids For IS 456. The results are tabulated below:-

Load Factors as per IRC 6-2016 Table B.2

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is
1)	SW =	1.35	1.35
2)	SIDL(W/o WC) =	1.35	1.35
3)	WC =	1.75	1.75
4)	VLL =	1.5	1.15
5)	BRAKING FORCE =	1.5	1.15
6)	WIND =	0.9	1.5
7)	Seismic =	1.5	-

i) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm
C2	28778.78	30620.56	3917.26
C4	28558.13	32346.50	4180.24
C8	28322.98	27655.35	4639.60
C10	28252.43	29737.11	5487.94
C14	28610.66	24449.30	5870.56
C16	28441.50	25518.34	6072.18
C20	28261.21	21921.79	6424.36
C22	28207.12	23517.81	7074.75
C25	25940.66	1901.11	916.74
C26	22380.09	19805.87	0.00

ii) Seismic Combinations (Factored Loads) (As per Cl:219.4 of IRC 6-2016))

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*

C2 to C7 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)

C7 to C13 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

Combinations	P in kN	M_{L1} in kNm	M_{T1} in kNm
C1	25790.53	12534.94	1746.59

Seismic Forces in Transverse Direction

Combinations	P in kN	M_{L2} in kNm	M_{T2} in kNm
C3	26326.45	24133.11	5401.66
C5	26276.67	24476.65	5444.87
C9	26330.54	24739.64	5546.13
C11	26282.81	25082.43	5706.41

PIER LOAD COMBINATIONS (QUASI PERMANENT COMBINATION-Table No B.3 of IRC6-2016)

(PARTIAL SAFETY FACTOR TAKEN AS PER IRC:6,2014, TABLE NO 3.3)

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*
1)	*SW =*	***1.00***	1
2)	*SIDL(W/o WC) =*	***1.00***	1
3)	*WC =*	***1.00***	1
4)	*VLL =*	***0.00***	0
5)	*BRAKING FORCE =*	***0.00***	*0*
6)	*WIND =*	***0.00***	*0*
7)	*Seismic =*	-	-

COMB	P in kN	ML in kNm	MT in kNm	Design BM = $\sqrt{(ML^2+MT^2)}$
C1	18553.39	6933.80	0.00	6933.80

Check for Slenderness Ratio

Size of Pier 2200.000 x 2000.000 *mm*

Clear cover = = 40.00 *mm*

Grade of Concrete = M - 60

Grade of Steel = = Fe - 550

As per IRC:112-2011, The minimum Ast for Pier is as follows,
1). (Length / radius of gyration) < 12 is "Pedestrian Column"
2). (Length / radius of gyration) > 12 is "Other Column"

Radius of Gyration (Rg) = Sqrt(I/A)

Rg = 635

I= 1.77467E+12 mm4

A = 4400000 mm2

Length of pier (Le) =		20034	*Effective lengthas per IRC:112-2011,Table 11.1,pg no 114, = l_0 *1.3*
Slenderness ratio	L / Rg =	31.55	**HENCE IT IS 'OTHER COLUMN'**

As per 11.2.2 of IRC 112-2011,Effective Length of Pier

(1) For compression members in regular frames, the effective length l_e is determined in the following way:

Braced Members:

$$l_e = 0.5 l_o \sqrt{\left(1+\frac{k_1}{0.45+k_1}\right) x \left(1+\frac{k_2}{0.45+k_2}\right)} \qquad \text{Eq.11.2}$$

Unbraced members:

$$l_e = l_o \; x \max of \left\{ \sqrt{\left(1+10.\frac{k_1.k_2}{k_1+k_2}\right)} ; \left(1+\frac{k_1}{1+k_1}\right) x \left(1+\frac{k_2}{1+k_2}\right) \right\} \qquad \text{Eq.11.3}$$

K1 =	0.1		
K2 =	0.1		
$\sqrt{1+\frac{10.K1.K2}{K1+K2}}$	=	1.22	
1+ K1/(1+K1) x (1+ K2/(1+K2)	=	1.190	
	l_o =	15411	mm
	l_e =	18.87	m

Limiting Slenderness ratio as per IRC:112-2011, Cl:11.2.1(2),

Limiting Slenderness ratio as per IRC:112-2011, Cl:11.2.1(2)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

N_{Ed}=	28778.78	kN			
Ø ef=	$\varphi(\infty,t_0).M_{oEqp}/M_{oEd}$				
$\varphi(\infty,t_0)$ =	*1.636*	*(As per IRC 112-2011,A2.5)*			
Mo_{Eqp} =	*6933.80*	KNm			
Mo_{ED} =	*32346.50*	KNm	Ac=	4400000	mm^2
Ø ef=	0.351		h= 2.Ac /U =	1047.6	mm
A=	0.934		fcd=	26.80	N/mm^2
w=	0.359		n=	0.24	
n=	0.24				
B=	1.311				
C=	0.7				
λ_{lim} =	34.71	>	18.87		

Hence OK

Limiting Slenderness ratio as per IRC:112-2011, Cl:11.2.1(2) (Direct Calculation)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

A= 0.70

Second order effects may be ignored if the slenderness ratio λ based on l_e as per Clause 11.2.2 is less than a certain value λ_{lim} as per Eq.11.1.

$$\lambda_{lim} = 20.A.B.C / \sqrt{n} \qquad \text{Eq.11.1}$$

where

A = $1/(1+0.2\phi_{ef})$

ϕ_{ef} *is effective creep ratio.*

$\phi_{ef} = \phi(\infty, t_o).\frac{M_{oEqp}}{M_{oEd}}$

M_{oEqp} = *First order B.M. in quasi-permanent load combination in SLS.*

M_{oEd} = *First order B.M. in design load combination in U.L.S.*

B = $\sqrt{1+2\omega}$

C = $1.7 - r_m$

ω = $A_s f_{yd} / (A_c f_{cd})$ *mechanical reinforcement ratio.*

A_s = *is the total area of longitudinal reinforcement.*

n = $N_{Ed} / (A_c f_{cd})$ *relative normal force*

r_m = M_{01} / M_{02} *moment ratio*

M_{01}, M_{02} *are the first order end moments at two ends of member as calculated from the analysis of structure, where* $|M_{02}| \geq |M_{01}|$.

If the end moments M_{01} & M_{02} *give tension on the same side,* r_m *should be taken positive (i.e. C* $\leq$ *1.7), otherwise negative (i.e. C >1.7).*

In the following cases, r_m *should be taken as 1.0 (i.e. C = 0.7):*

- For unbraced members in general.
- For braced members in which the first order moments arise predominantly from imperfections or transverse loading.

B=	1.10		
C=	0.70		
Ac=	4400000	mm2	
fcd=	26.80	N/mm2	**(α*fck/λ_m)** *cl:6.4.2.8(1)*
N_{Ed}=	28778.78	kN	
n=	0.24		
λ_{lim} =	21.82		
<	18.87		**Hence OK**

Design of Vertical Reinforcement

Check for design of Bi-axial Column (For Rectangular column)

As per 8.3.2(4)of IRC 112-2011, Pg no 75
For Rectangular column,

$$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{\alpha}+\left(\frac{M_{Edy}}{M_{Rdy}}\right)^{\alpha}\le 1 \qquad \text{Eq. 8.3}$$

where
M_{Edx}, M_{Edy} Design moment around the respective axis, including nominal 2nd order moments.
M_{Rdx}, M_{Rdy} Moment resistance in the respective direction
Exponent as follows;
- for circular and elliptical cross-sections: $\alpha = 2$
- for rectangular cross-sections:

N_{Ed}/N_{Rd}	0.1	0.7	1.0
α =	1.0	1.5	2.0

With linear interpolation for intermediate values.
N_{Ed}= design value of axial force.
$N_{Rd}= A_c f_{cd} + A_s f_{yd}$, design axial resistance of section.

Size of Pier = 2000 x 2200.00

Combinations	**Normal Combination**			**Seismic Longitudinal**	**Seismic Transverse**	As per SP-16, Cl 3.3, Pg no 104,
Grade of Concrete	60			60.00	60	N/mm2
Grade of Steel	550			550.00	550	N/mm2
b	2000.00			2000.00	2000.00	
d	2200.00			2200.00	2200.00	
Combinations	C2	C4	C21	C1	C10	
Pu	28778.78	28558.13	27560.36	25790.53	26100.36	kN
Mux	30620.56	32346.50	22030.73	12534.94	24347.03	kN-m
Muy	3917.26	4180.24	10471.67	1746.59	6559.96	kN-m
d'/D	0.032			0.032	0.032	
α	1.07	1.07	1.06	1.05	1.05	(for Rectangular as per IRC:112-2011, Cl:8.3.2, Pg no 75)
Assume Pt	**1.800**	**1.800**	**1.800**	**1.800**	**1.800**	
Ast Required (As pro)	79200.0	79200.0	79200.0	79200.0	79200.0	
p / fck	0.0300	0.0300	0.0300	0.0300	0.0300	
Pu/(fck*b*D)	0.109	0.108	0.104	0.098	0.099	
Mu/(fck*b*D*D)	0.080	0.080	0.080	0.080	0.080	(from Chart 47, using SP-16)
Mu/(fck*D*b*b)	0.080	0.080	0.080	0.080	0.080	(from Chart 47, using SP-16)
Mu (Longer Direction)	46464.0	46464.0	46464.0	46464.0	46464.0	kN-m
Mu (shorter Direction)	42240.0	42240.0	42240.0	42240.0	42240.0	kN-m (Resisting moment for provided steel)
Interaction ratio	$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{\alpha}+\left(\frac{M_{Edy}}{M_{Rdy}}\right)^{\alpha}\le 1$			(12,534.94/46,464.00) ^1.05 + (1,746.59/42,240.00) ^1.05	(24,347.03/46,464.00) ^1.05 + (6,559.96/42,240.00) ^1.05	
				0.25 + 0.04	0.51 + 0.14	
	0.72	**0.76**	**0.68**	= 0.29	= 0.65	< 1.00

	Hence O.K			Hence O.K	Hence O.K	
Total Area of steel required	79200	79200	79200	79200	79200	mm^2
Ast Provided =	Y32	-	106 Nos	Y32 - 106 Nos	Y32 - 106 Nos	
	84848.1			84848.1	84848.1	
Total Area of Steel provided	84848.13			84848.13 mm^2	84848.13 mm^2	
Provided pt	1.986			1.986	1.986	
	Hence O.K			Hence O.K	Hence O.K	

As per IRC 112-2011 Cl:16

Ast.Min =	6619.119 mm^2	$0.1N_{Ed}/f_{yd}$
Ast.Min =	8800 mm^2	0.002 Ac
Ast.Min =	10560 mm^2	0.0024 Ac
Ast.Max =	176000 mm^2	0.004Ac

Lateral ties

As per IRC:112-2011, Cl:16.2.3,

Dia of lateral tie is max of below,

i). 8 mm

ii). One quarter of max dia of longitudinal bars 8 mm

Hence provide 8 mm

Spacing of lateral tie is min of below,

i). 12 times min dia of longitudinal bars 384.00 mm

ii). The least dimension of the column 1555.63 mm

iii). 200 mm 200.00 mm

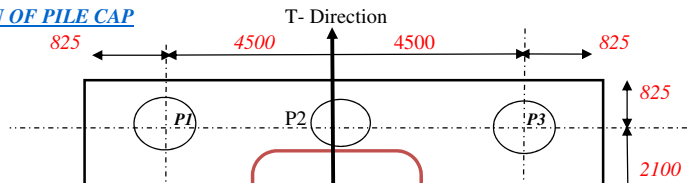
Hence provide 150 mm

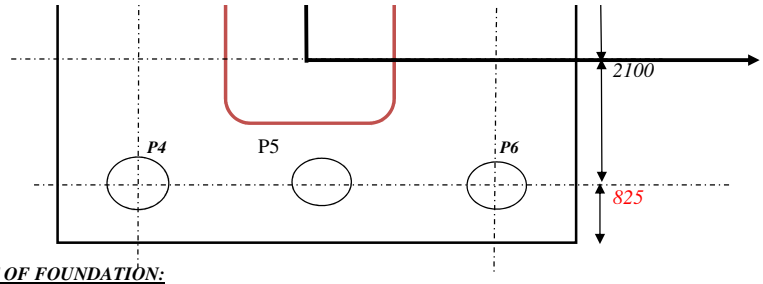
Hence provide Y - 8 @ 150 c/c

Summary

1	*Pier Size =*	*(Circular Pier*	2200 mm Dia)	
2	*Grade of concrete =*		*M - 60*	
3	*Grade of steel =*		*Fe - 550*	
4	*Main Longitudinal reinforcement=*		**Y- 32 of 25 Nos**	**per each face of Wall**
5	*Lateral Ties =*		***Y - 8 @ 150 c/c***	**above the confinement reinforcemnt.**

4) DESIGN OF PILE CAP





SELF WEIGHT OF FOUNDATION:

Width of Pile Cap =	*10650.0*	*mm*
Length of Pile Cap =	*5850.0*	*mm*
Thickness of Pile Cap =	*2100.0*	*mm*
Height of soil =	*300.0*	*mm*
Sw of the Pile Cap=	*3270.9*	*kN*
Wt of soil =	*347.4*	*kN*

Load Factors as per IRC 6-2016 Table B.3

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying
1	SW =	1	1
2	SIDL(W/o WC) =	1	1
3	WC =	1.2	1.2
4	VLL =	1	0.75
5	BRAKING FORCE =	1	0.75
6	WIND =	0.6	1
7	Seismic =	1	-

Load Combinations

C1 to C6 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + FF)*

C7 to C12 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + FF)*

C13 to C18 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C18 to C24 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C25 = *DL+SW+WIND ON UNLOADED STURCTURE*

C26 = *Launching Girder Case*

i) Normal and Wind Combination (Unfactored Loads)

Combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	H/Pile	*Remarks*
C2	24529.6	22743.5	2889.6	1114.2	132.4	1122.069	187.0115	Normal Comb
C4	24382.5	24046.0	3064.9	1189.2	132.4	1196.506	199.4177	Normal Comb
C8	24225.8	20701.9	3371.1	1083.4	132.4	1091.443	181.9072	Normal Comb
C10	24178.7	22254.3	3936.7	1164.4	132.4	1171.870	195.3117	Normal Comb
C14	24386.4	17610.1	4369.0	866.0	220.7	893.690	148.9483	Wind Comb
C16	24276.0	18586.9	4500.5	922.2	220.7	948.247	158.0412	Wind Comb
C20	24158.5	16062.8	4730.2	842.9	220.7	871.289	145.2149	Wind Comb
C22	24123.2	17223.5	5154.3	903.6	220.7	930.174	155.0290	Wind Comb
C25	24521.1	701.2	693.2	55.2	220.7	227.470	37.9117	Wind Comb
C26	16577.8	15070.5	0.0	190.3	0.0	190.250	31.7083	

ii) Seismic Combinations (Unfactored Loads)

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*

C2 to C7 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)

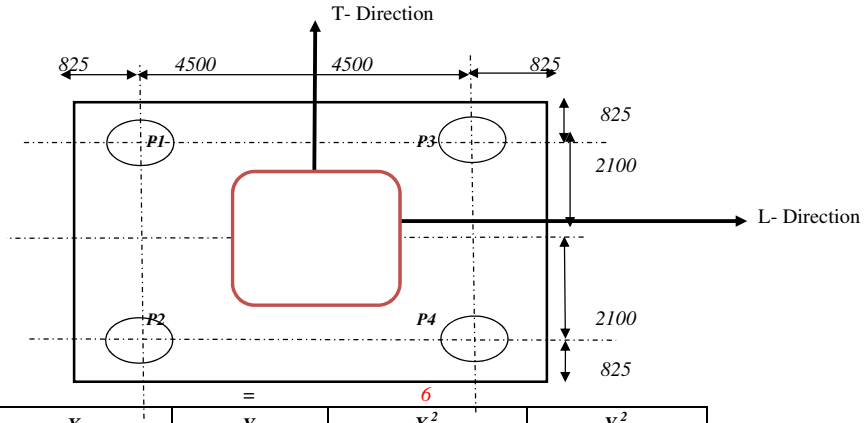
C7 to C13 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	H/Pile	Remarks

C1	22462.54	13286.92	1694.55	614.63	183.55	641.454	106.9090	Seismic
Seismic Forces in Transverse Direction								
C3	22819.83	18441.20	5401.47	947.87	272.06	986.138	164.3563	Seismic
C5	22786.64	18701.69	5427.04	962.85	271.69	1000.450	166.7417	Seismic
C9	22822.55	18578.40	5497.78	974.54	272.06	1011.806	168.6343	Seismic
C11	22790.73	18869.42	5601.40	990.67	271.69	1027.249	171.2081	Seismic

CALCULATION OF PILE REACTION AND DESIGN OF PILE CAP



Number of piles = 6

Pile No.	*X*	*Y*	X^2	Y^2
1	-4.50	2.10	20.25	4.41
2	0.00	2.10	0.00	4.41
3	4.50	2.10	20.25	4.41
4	-4.50	-2.10	20.25	4.41
5	0.00	-2.10	0.00	4.41
6	4.50	-2.10	20.25	4.41
			81.00	26.46

Pile Reactions

i) Normal and Wind Combination (Unfactored Loads)

COMB	P in kN	M_L in kNm	M_T in kNm	Pmax	Pmin	Remarks
C2	24529.6	22743.5	2889.6	5581.1	2595.4	*Normal Comb*
C4	24382.5	24046.0	3064.9	5642.9	2484.6	*Normal Comb*
C8	24225.8	20701.9	3371.1	5455.3	2620.0	*Normal Comb*
C10	24178.7	22254.3	3936.7	5578.6	2481.0	*Normal Comb*
C14	24386.4	17610.1	4369.0	5389.5	2739.3	*Wind Comb*
C16	24276.0	18586.9	4500.5	5435.8	2656.2	*Wind Comb*
C20	24158.5	16062.8	4730.2	5294.2	2758.6	*Wind Comb*
C22	24123.2	17223.5	5154.3	5386.5	2654.6	*Wind Comb*
C25	24521.1	701.2	693.2	4180.8	3992.9	*Wind Comb*
C26	20196.14	15070.54	0.00	4203.3	2528.8	

Maximum And Minimum Pile Loads

Max	Min

Max Pile Load	***Pile Capacity***

Normal Load Combination	5642.89kN	2233.27kN	5642.9kN	< 6000.00	(Normal Load combination)
Wind Combination	5493.47	2406.99	5493.5kN	< 1.25x 6000.00	(Wind Load Combination)

ii) Seismic Combinations (Unfactored Loads)

COMB	P in kN	ML in kNm	MT in kNm	Pmax	Pmin
C1	22462.5	13286.9	1694.5	4616.4	2871.1
C3	22819.8	18441.2	5401.5	5256.5	2350.1
C5	22786.6	18701.7	5427.0	5267.5	2328.1
C9	22822.5	18578.4	5497.8	5272.2	2335.3
C11	22790.7	18869.4	5601.4	5291.3	2305.6

Maximum And Minimum Pile Loads

Max	Min	Max Pile Load	*Pile Capacity*	
5291.31kN	2268.10kN	5291.31kN	< 1.25x 6000.00	(Seismic Load combination)

iii) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	Pmax	Pmin
C2	33715.59	34114.04	4334.34	7858.49	3380.05
C4	33494.94	36067.78	4597.32	7951.12	3213.86
C8	33259.79	31051.67	5056.68	7669.72	3416.88
C10	33189.24	33380.30	5905.02	7854.65	3208.43
C14	33547.47	25505.15	6565.70	7529.29	3653.21
C16	33378.31	27164.09	6767.32	7609.26	3516.85
C20	33198.03	24619.48	7119.50	7465.79	3600.22
C22	33143.94	26404.76	7769.89	7607.58	3440.40
C25	31343.53	2090.43	1039.82	5422.58	5025.26
C26	27264.79	20345.22	0.00	5674.42	3413.84

Maximum And Minimum Pile reactions

	Max	Min
Normal Load Combination	7951.12kN	2836.83kN
Wind Combination	7676.88kN	3155.51kN

iv) Seismic Combinations (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	Pmax	Pmin
C1	30923.20	19926.38	2342.95	6446.84	3860.90
C3	31489.48	27660.59	8102.21	7427.98	3068.52
C5	31437.64	28051.34	8140.56	7444.09	3035.12
C9	31526.92	27859.95	8246.67	7456.76	3052.21
C11	31483.71	28386.36	8402.10	7491.14	3003.43

Maximum And Minimum Pile reactions

Max	Min
7496.77kN	2934.73kN

Design of pile cap:

PILE CAP FOR 4 PILE GROUP

Pile Spacing in L direction	=	9.00 m
Pile Spacing in T direction	=	4.20 m
Pile diameter	=	1.35 m
Distance between edge of pile to edge of pile cap	=	0.15 m

Depth of pile cap	=	2.1 m
Pile cap dimension along L direction	=	10.65 m
Pile cap dimension along T direction	=	5.85 m
Grade of concrete	=	M - 35 Mpa
Grade of steel	=	550 Mpa

Pile reaction:

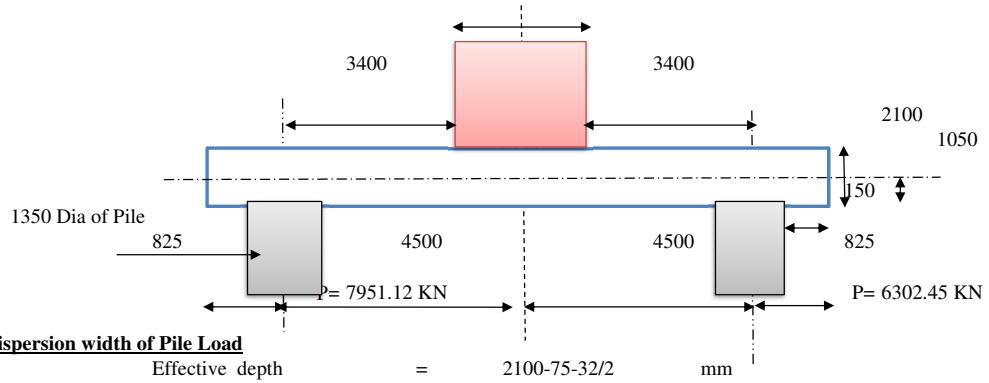
Critical pile reaction:

Pile Name	Pmax	Pmin
Pile Loads for Design of Pile Cap	7951.12	5025.26

P7 P8 P9
5619.27 5619.27 5619.27

Bending Moment in Longitudinal Direction

Since the Pile reaction of individual piles does not overlap at mid depth of the Pile cap, Forces are calculated w.r.t maximum reaction and same forces considered for the design of Pile cap in both Longitudinal and transverse direction.



a) Dispersion width of Pile Load

Effective depth	=	2100-75-32/2	mm
Effective depth	=	2009	mm

Clear Distance between pile to pile = 6300mm > 1050mm

Hence Dispersion Dose not over lap

Effective width of dispersion	=	150+1350+1050	
	=	2550	mm
Pile reaction	=	7951.12	kN
Bending Moment	=	7,951.12x3.400=	27033.82 kNm
B.M /meter Width =		10601.50	

b) Bending moment due to dispersion of Pier Load

Maximum Axial force for Pier (Factored Combinations) =	=	28778.8 KN	
Width of dispersion from Pier on pile cap (B_{eff})	=	2200+1050+1050	= 4300 mm
Dispersed Area of Pier	=	8.600 m^2	
Pier Load per dispersed area of pier (factored)	=	3346.37 KN/m^2	

Moment due to this load =	=	3346.37x1.05X1.05/2	=	0.0	KNm/m	
Resultant Moment due to Pile Load and Pier load	=	**10601.50 KNm/m**				
Grade of Concrete	=	**35** Mpa				
Grade of steel	=	**550** Mpa				
Clear cover	=	**75** mm				
Dia of main bar	=	**32** mm				

Effective depth required = $\sqrt{\dfrac{10601 \times 1000000}{0.133 \times 35 \times 1000}}$

= 1509.12 mm

Effective depth provided = 1977 mm > **SAFE**

Ast required = 12442.98 mm^2

As per IRC:112-2011, Cl:16.5.1.1, Pg no 175, (Table 6 of IRC 112) fctm = 2.8

Ast max is not greater than **0.025 Ac** Ast min = 0.0013* b*d = 2570.10 mm2

Total Ast + Asc is not greater than **0.04 Ac** Ast min = 0.26*fctm *b.d/fyd = 3025.34 mm2

Hence **Required A_{st}** = **12442.98** mm2

Provide Y - 32 @ + Y - 32 @ 100 C/C Ast $_{Provided}$ = 16085.0 **HENCE O.K**

Check for ultimate shear Resistence

As per Cl:10.3.2 IRC 112, Check for Ultimate Shear resistence is given by

1) The design shear resistance $V_{Rd.c} \geq V_{Ed}$

2) The design shear resistance of the member without shear reinforcement $V_{Rd.c}$ is given by:

$$V_{Rd.c} = \left[0.12K(80\rho_1 f_{ck})^{0.33} + 0.15\sigma_{cp}\right] b_w.d$$

Subject to a minimum of $v_{Rd.c} = (v_{min} + 0.15\sigma_{cp})\, b_w.d$ **Eq. 10.1**

$K = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ where d is depth in millimeters. **Eq. 10.2**

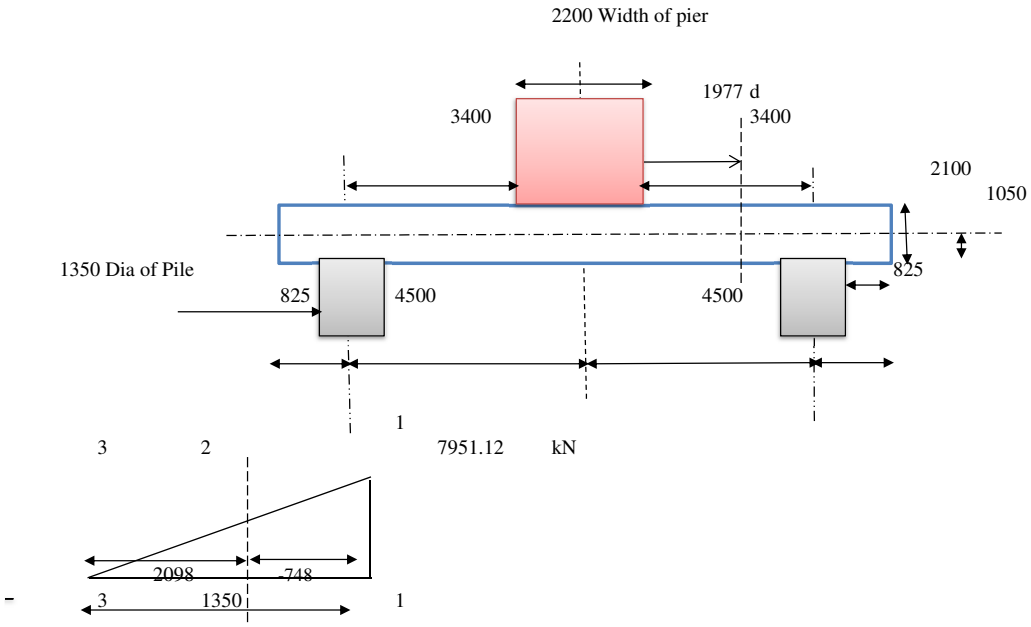
and $v_{min} = 0.031K^{3/2} f_{ck}^{1/2}$, **Eq. 10.3**

σ_{cp} is limited to $0.2 f_{cd}$ (MPa) where $\sigma_{cp} = N_{Ed}/A_c < 0.2 f_{cd}$ (MPa)

$\rho_1 = \frac{A_{sl}}{b_w.d} \leq 0.02$ (Fig.10.5)

K=	1.32		
p_1 =	0.008136042	<	0.20
σ_{cp} =	0.0000	<	3.12
VRD.c =	1803.08	KN	
>	3118.09	KN	

Check for shear in Longitudinal Direction:



Effective depth	=	1977 mm
Critical section for shear = d from face of pier		
	=	1977 mm
Distance from face of Pier to inner face of end of pile		2725.0 mm
Distance from face of Pier to outer face of pile		4075.0 mm

Since the Critical section is inside the end pile edge,Pile Cap to be designed for Shear

S.F at Section 1- 1=	7951.12	kN
S.F at Section 3-3=	0	kN
S.F at Section 2-2=	7951.12	kN

SF At Critical Section (2-2)	=	7951.12 kN	
Dispersion width available	=	2550 mm	
Toatl Design S.F (V)	=	7951.12	kN
Toatl Design S.F (V)/m width	=	3118.09	kN

Check for yielding of steel in shear as per IRC:112-2011, Cl 10.3.3.2

VRDS = VNS = (ASW / S) * z * fywd * cot θ

Where,

ASW = C/S area of shear reinforcement

s = spacing of stirrups

z = Liver arm, for RCC = 0.9 * dpro

fywd = Design yield strength of shear reinforcement = 0.8 * fy

f_{ywd} = 478.50 N/mm^2 (0.87/1.15 fy)

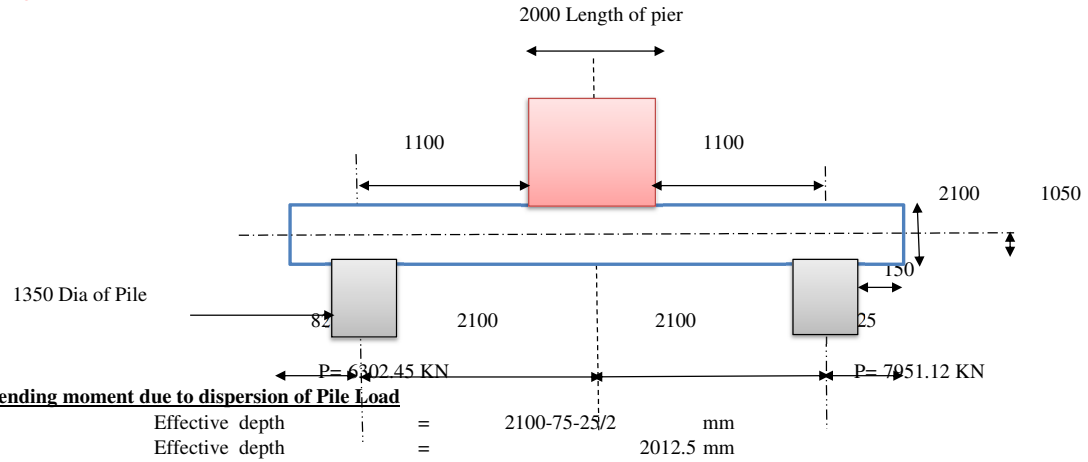
Assuming 5 L Y - 12

Spacing required (s) = (ASW * z * fywd * cot θ / VNS

s = 154.41 mm **=120** mm

Provide **5 - L Y 12 @ 120 mm c/c per m**

Bending Moment in Transverse Direction:



a) Bending moment due to dispersion of Pile Load

Effective depth = 2100-75-25/2 mm

Effective depth = 2012.5 mm

Clear Distance between pile to pile = 750 mm

Hence Dose not over lap

Effective width of dispersion = 150+1350+1050

= 2550 mm

Pile rection = 7951.12 kN

Bending Moment = 7,951.12x1.10= 8746.24 kNm

B.M /meter Width = 3429.90

b) Bending moment due to dispersion of Pier Load

Maximum Axial force for Pier (Factored Combinations) = = 28778.8 KN

Width of dispersion from Pier on pile cap (B_{eff}) = 2000+1050+1050 = 4100 mm

Dispersed Area of Pier = 9.020 m^2

Pier Load per dispersed area of pier (factored) = 3190.55 KN/m^2

Moment due to this load = = 3190.55x1.05X1.05/2 = 1758.8 KNm/m

Resultant Moment due to Pile Load and Pier load = **3429.90 KNm/m**

Design

For M-max = **3429.90 kN-m/m**

Grade of Concrete = **35** Mpa

Grade of steel = **550** Mpa

Clear cover = **75** mm

Dia of main bar = **25 mm**

Effective depth required = $\sqrt{\frac{3430 \times 1000000}{\quad}}$

$$= \sqrt{\frac{0.133 \times 35}{1000}}$$

= 858.38 mm

Effective depth provided = 1988 mm > **SAFE**

Ast required = 3717.63 mm^2

As per IRC:112-2011, Cl:16.5.1.1, Pg no 175,

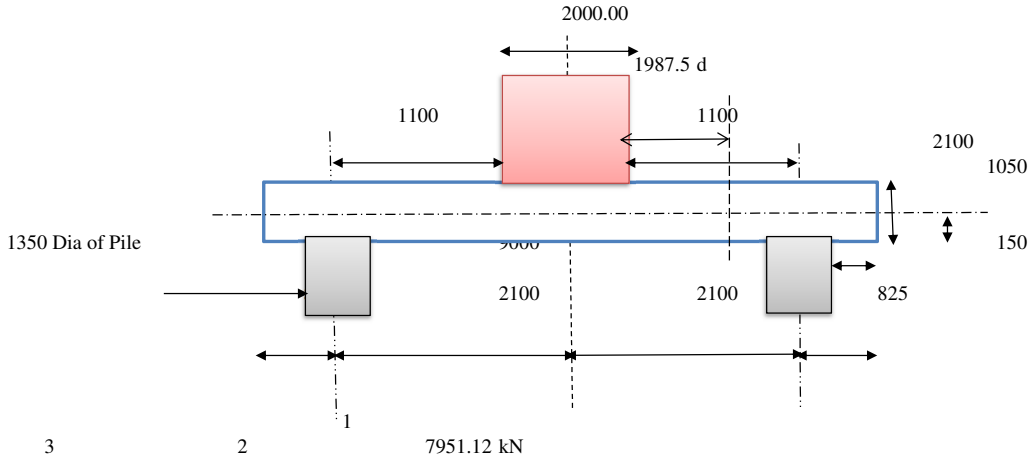
Ast max is not greater than **0.025 Ac** Ast min = 0.0013* b*d = 2570.1 mm2

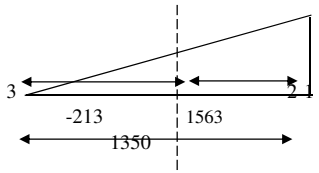
Total Ast + Asc is not greater than **0.04 Ac** Ast min = 0.26*fctm *b.d/fyd = 3025.3 mm2

Hence **Required A_{st}** = **3717.63** mm2

Provide Y - 25 @ 100 C/C $Ast_{Provided}$ = 4908.7 **HENCE O.K**

Check for shear in Transverse Direction:





Clear Distance between pile to pile	=	75 mm	
Effective depth	=	1987.5 mm	
Critical section for shear = d from face of pier			
	=	1987.5 mm	
Distance from face of Pier to inner face of end of pile		425.0 mm	
Distance from face of Pier to outer face of pile		1775.0mm >	1987.5mm

Since the Critical section is beyond pile edge, Shear will not govern the design.

Stress Check calculation for Pile Cap (For Rare Combiantion-Table No 3.3 of IRC6-2014)

(As per IRC 112-2011, Cl:12.3.4)

		Longitudinal	Transverse	
Width of pile beam =	b=	**1000**	**1000**	mm
Thickness of Beam (mm)	h =	2100	2100	mm
Dia of main Bar (mm)		32	25	mm
Effective Depth (deff) mm		1977	2013	mm
Ast pro (mm2)		16084.95	4908.74	mm^2
Max Moment (kN-m)		7523.85	2434.19	N/mm^2
Es (N/mm^2)		200000	200000	N/mm^2
Ec.eff (N/mm^2)		12955	12955	
m = α = Es/Ecm		15.44	15.44	
X_U (mm) =		773.20	481.67	mm
L.A (mm) =		1652.26	1810.20	mm
Stress in Steel (N/mm2)		283.10	273.94	N/mm^2
Permissible stress in steel		440	440	N/mm^2
Check for stree in steel		Hence OK	Hence OK	
Stress in Concrete (N/mm2)		11.78	5.58	N/mm^2
Permissible stress in concrete		13	13	N/mm^2
Check for stree in concrete		Hence OK	Hence OK	

L.A= d - 0.42Xu

Stress in Steel = M/ (Ast xL.A)

Stress in concrete= M/ (0.5.Xu.b.(L.A)

$b X_u^2/2 = m Ast (d-X_u)$

a		500.00	500.00
b		248311.48	75778.65
c		-490911802.56	-152504534.98
Xu 1 =		773.20	481.67
Xu 2=		-1269.82	-633.23

Maximum Pile load = 4203 kN C26

Dispersion width due to Pile= 2.550 m

Lever Arm for BM = 1.100 m

Bending Moment due to Pile = 1813.18 kNm

CRACK WIDTH CALCULATION (For Quasi Permanent Combiantion-Table No 3.3 of IRC6-2014)

Dia of main Bar (mm)	32	25
Spacing of Bars (mm)	100	100
Max Moment (kN-m)	5604.37	1813.18
Ast pro As (mm^2)	16084.95	4908.74
C_{min} (mm)	75	75
a_{cr} (mm)	87.83	88.28
h (mm)	2100.00	2100.00
d (mm)	1977.00	2012.50
Es (N/mm^2)	200000	200000

Ec.eff (N/mm^2)		12955	12955
m = α = Es/Ecm		15.44	15.44
Xu (mm)		773.20	481.67
s_{sc} (N/mm^2)		210.88	204.05
k_t =		0.5	0.5
$f_{ct,eff}$ (N/mm^2)		3	3
$A_{c,eff}$ = b*$h_{c,eff}$ (mm^2)		307500.00	218750.00
$h_{c,eff}$ least of	2.5 (h - d)	307.5	218.8
	(h - Xu) / 3	442.3	539.4
	h / 2	1050.0	1050.0
$r_{P,eff}$ =		0.0523	0.0224
e_{sm} - e_{cm} =		0.00080	0.00057
		≥ 0.00063	≥ 0.00061
e_{sm} - e_{cm} =		0.00080	0.00061
IRC 112-2011	k1 =	0.8	0.8
	k2 =	0.5	0.5
Spacing	5(c + dia/2) =	455.00	437.50
Case(i)	$S_{r,max}$ (mm)=	359.00	444.39
Case(ii)	$S_{r,max}$ (mm) =	1724.84	2103.83
$S_{r,max}$ (mm) =		359.00	444.39
W_k (mm) =		0.285	0.272
Check for Crack Width		**Hence OK**	**Hence OK**

Ecm = 32000 MPa
Ac = 2100000 mm^2
u= 6200 mm
2Ac/u = 677.4 mm

210.8767602

As per IRC:112-2011, table-6.9, for RH-80%, & 28 days age loading

ø 1= 1.7 for 150
ø 2= 1.5 for 600
ø = **1.47** for 677

Ec,eff = Ecm / (1+ ø)

Ec,eff = **12955.47** MPa

Es = 200000.00 MPa
m = 15.44

Check for Punching Shear

Maximium pile load = 7951.12 kN

Allowable punching shear as per IRC:112-2011, Cl:10.4.5, Pg no 104,

Check For Punching Shear,as per cl. 10.4.3, IRC:112-2011

V_{min} 2d/a = 7.412

K = 1.316 < 2

v_{min} = 0.277 N/mm^2

r_l = 0.00423 < 0.02

v_{Rd} = 11.749 N/mm^2 > 7.41

Punching shear stress $v_{ED} = \dfrac{\beta \times V_{ED}}{u_i \times d}$

β = 1

v = 0.532 N/mm^2

fcd	=	15.63 N/mm^2				
$v_{Rd,max}$	=	4.16 N/mm^2				

a) At the basic control perimeter ui (At Corner Pile)
(2d/2+1000+2d/2)

u_i	=	4374.6 mm	(From Auto Cad)			
v_{ED}	=	0.919 N/mm^2	<	4.16	**SAFE**	

v_{Rdmax}	>	v_{Ed}			
4.16	>	0.919	HENCE	**SAFE**	

5) Design of Pier Pile

The Pile is Designed for Axial Load and BM. The Top fixity is considered at the Bottom of Pile cap and Bottom Fixity is calculated as per Annex C, IS2911- Part1, SEC4 (2010)

Dia of Pile		*1350 mm*		
Grade Of Concrete	*M*	*M35*		
ECONCRETE	*Fe*	*32000.00 MN/m2*	(As per IRC 112-2011,Table 6.5)	
M.I)Pile		*0.163065197 m4*		

T= $5\sqrt{(EI/\eta_h)}$

R= $4\sqrt{(EI/KB)}$

From Table - 5, η_h = (for Medium Sand) *2.840 MN/m3 (Conservatively)*

Corresponding to N value of 20

Table 5 Modulus of Subgrade Reaction for Granular Soils, η_h, in kN/m^3
(Clauses C-2.1 and C-2.3.1)

Sl No.	Soil Type	N (Blows/ 30 cm)	Range of η_h kN/m^3 × 10^3 Dry	Submerged
(1)	(2)	(3)	(4)	(5)
i)	Very loose sand	0-4	< 0.4	< 0.2
ii)	Loose sand	4-10	0.4-2.5	0.2-1.4
iii)	Medium sand	10-35	2.5-7.5	1.4-5.0
iv)	Dense sand	> 35	7.5-20.0	5.0-12.0

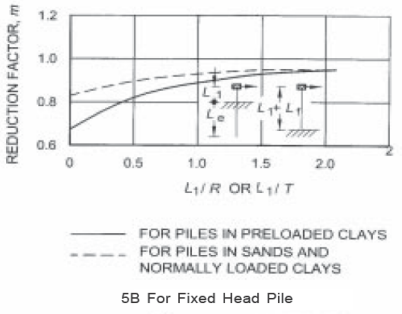
NOTE — The η_h values may be interpolated for intermediate standard penetration values, *N*.

C-2.3.1 *For Piles in Sand and Normally Loaded Clays*

Stiffness factor *T*, in m = $\sqrt[5]{\frac{EI}{\eta_h}}$

η_h = modulus of subgrade reaction, in MN/m^3 (*see* Table 5).

Top Fixity Level(Bottom Of Pile Cap)			*895.125 m*			
	L1=		*0.000 m*			
Calculating,						
T=	*4.50 m*		*4.50 m*			
	L1/T=		*0.00 m*			
From Fig 4 (IS 2911-SeC 4,2010)		*LF/T =*	*2.20*			
Hence, LF =			*9.89 m*			
Lever Arm =	*Top Fixity*	-	*Scour Level*	+	*Lf*	
	895.125	-	*895.125*	+	*9.891*	
	L.A =		*9.9 m*			
BM in Pile =	*HX9.89/2=*	=				
Redution Factor	=		*0.85 From Fig 5 (IS 2911-SeC 4,2010)*			
Final L.A	=		*8.41 m*			
Self Weight of the Pile =		=	*262.062 kN*			



5B For Fixed Head Pile

i) Normal & Wind combinations (Factored Loads)

Load Case	*P(kN)*	*HL/Pile (kN)*	*HT/Pile(kN)*	*H=√HL^2+HT^2*	*BM(kNm)*	*Remarks*
C2	3380.0	*278.56*	*33.10*	*280.52*	*1203.99*	*Normal Comb*
C4	3213.9	*297.29*	*33.10*	*299.13*	*1282.22*	*Normal Comb*
C8	3416.9	*270.85*	*33.10*	*272.86*	*1171.80*	*Normal Comb*
C10	3208.4	*291.09*	*33.10*	*292.97*	*1256.33*	*Normal Comb*
C14	3653.2	*221.01*	*55.17*	*227.79*	*982.33*	*Wind Comb*
C16	3516.8	*235.37*	*55.17*	*241.75*	*1041.01*	*Wind Comb*
C20	3600.2	*215.10*	*55.17*	*222.06*	*958.24*	*Wind Comb*
C22	3440.4	*230.62*	*55.17*	*237.13*	*1021.58*	*Wind Comb*
C25	5025.3	*13.79*	*55.17*	*56.87*	*263.79*	*Wind Comb*
C26	3413.8	*31.71*	*0.00*	*31.71*	*158.03*	

	P(kN)	*BM(kNm)*	*Pu / fck * D * D*	*Mu / fck * D * D * D*	*As per SP:16 p/fck*	*Asc = p*(area of pier)*	*Combination*
Max P Case	5025.3	*263.79*	0.079	0.003	*0.010*	***5009.86***	C25
Max BM Case	3213.9	*1282.22*	0.050	0.015	*0.010*	***5009.86***	C4
Min P Case	2836.8	*1177.79*	0.044	0.014	*0.010*	***5009.86***	C9

ii) Seismic combinations (Factored Loads)

Load Case	*P(kN)*	HL/Pile (kN)	*HT/Pile(kN)*	*H=√HL^2+HT^2*	BM(kNm)	*Remarks*
C1	3860.9	*151.43*	*14.90*	*152.16*	*664.38*	*Seismic*
C3	3068.5	*231.75*	*50.63*	*237.22*	*1021.95*	*Seismic*
C5	3035.1	*235.50*	*50.53*	*240.86*	*1037.27*	*Seismic*
C9	3052.2	*237.34*	*50.63*	*242.68*	*1044.94*	*Seismic*
C11	3003.4	*241.14*	*50.53*	*246.38*	*1060.47*	*Seismic*

	P(kN)	*BM(kNm)*	*Pu / fck * D * D*	*Mu / fck * D * D * D*	*As per SP:16 p/fck*	*Asc = p*(area of pier)*	*Combination*
Max P Case	3860.9	*664.38*	*0.061*	0.008	*0.0100*	***5009.86***	C1
Max BM Case	3003.4	*1060.47*	*0.047*	0.012	*0.0100*	***5009.86***	C11
Min P Case	2934.7	*1034.10*	*0.046*	0.012	*0.0100*	***5009.86***	C12

iii) Stress Check for Pile Loads Rare combination-Table No B.3 of IRC6-2016

Normal & Wind combinations

Check For Stresses : The Pile is Checked for Combined Axial and Bending using in house Computer programme The Stress Calculation is done for both Maximum reaction & BM and Minimum Reaction & BM Finding the Area of steel for Piles, for factored load combination

Load Case	**P(kN)**	**HL/Pile (kN)**	**HT/Pile(kN)**	**H=√HL^2+HT^2**	**BM(kNm)**	*Remarks*
C2	*2595.41*	*185.70*	*22.07*	*187.01*	*786.2*	*Normal Comb*
C4	*2484.62*	*198.19*	*22.07*	*199.42*	*838.3*	*Normal Comb*
C8	*2619.97*	*180.56*	*22.07*	*181.91*	*764.7*	*Normal Comb*

C10	2481.00	194.06	22.07	195.31	821.1	Normal Comb
C14	2739.31	144.34	36.78	148.95	626.2	Wind Comb
C16	2656.22	153.70	36.78	158.04	664.4	Wind Comb
C20	2758.62	140.48	36.78	145.21	610.5	Wind Comb
C22	2654.59	150.60	36.78	155.03	651.7	Wind Comb
C25	3992.87	9.19	36.78	37.91	159.4	Wind Comb
C26	2528.77	31.71	0.00	31.71	133.3	

	P(kN)	BM(kNm)	Pt	Stress in Conc (N/mm2)	Stress in Steel (N/mm2)	Permissible Stress in Concrete	Permissible Stress in Steel	Combinations
Max P Case	3992.9	159.38	0.42	5.62	18.83	16.8	440	C25
Max BM Case	2484.6	838.33	0.42	8.20	114.72	16.8	440	C12
Min P Case	2233.3	768.71	0.42	7.52	127.39	16.8	440	#N/A

As per IRC:112-2011, table-6.9, for RH-80%, & 28 days age loading

ø 1= 1.7 for 150
ø 2= 1.5 for 600
ø = **1.47** for 675

Ec,eff = Ecm / (1+ ø)

Ecm = 32000 MPa
Ac = 1431388.153 mm^2
u= 4241.150082 mm
2Ac/u = 675 mm
Ec,eff = **12955.47** MPa
Es = 200000.00 MPa
m = 15.44

Design of Reinforcement:

Dia of Pile = 1350 mm
Clear cover = 75 mm
Dia of Tie = 8 mm
*core dia = Dia of pier - 2*clear cover* = 1200 mm
Grade of Concrete = M - 35 mm
Grade of Steel = Fe - 550 N/mm2
N/mm2

As per IRC:112-2011, The minimum Ast for Compression member is as follows,
1). (Length / radius of gyration) < 12 is "Pedestrian Column"
2). (Length / radius of gyration) > 12 is "Other Column"

Radius of Gyration (Rg) = Sqrt(I/A)
I= 1.63044E+11 mm4
A = 1431388.153 mm2
Rg = 338
Length of pier (L) = 9891
L / Rg = 29 *HENCE IT IS 'OTHER COLUMN'*

Design of Vertical reinforcement

d' = 95.00
d' / D = 0.07
refer Chart 56 of SP : 16
p / fck = 0.010
p = 0.35
Asc = p(area of pier)/100* = 5009.86 mm2
0.15% of C/A = 2147.08 mm2
Minimum Ast required = (0.10N/fyd) or 0.002 C/A
0.10N/fyd = 1050.74 mm2
1050.74 mm2
0.002 C/A = 2862.78 mm2
or 2862.78 mm2
There fore Ast min = 2862.78 mm2
However, For Piles, Minimum Pt = 0.4%
Ast= 5725.55 mm2
Asc Required = 6011.83 mm^2
Pt = 0.42 6011.83 *(from rare Combination)*

Provide *Y- 20 of* *20 Nos* *6283.19 mm²* *Hence OK* Pt Provided = *0.439*

Lateral ties

As per IRC:112-2011, Cl:16.2.3,

Dia of lateral tie is max of below,

i). *8 mm*

ii). *One quarter of max dia of longitudinal bars* *5 mm*

Hence provide *8 mm*

Spacing of lateral tie is min of belo,

i). *12 times min dia of longitudinal bars* *240.00 mm*

ii). *The least dimension of the column* *954.59 mm*

iii). *200 mm* *200.00 mm*

Hence provide *150 mm*

Hence provide *Y - 8 @* *150 c/c*

1	*Pile Size =*	*1350 mm*	
2	*Grade of concrete =*	*M - 35*	
3	*Grade of steel =*	*Fe - 550*	
4	*main reinforcement =*	*Y- 20 of 20 Nos*	*6283.19 mm²*
5	*Lateral Ties =*	*Y - 8 @ 150 c/c*	

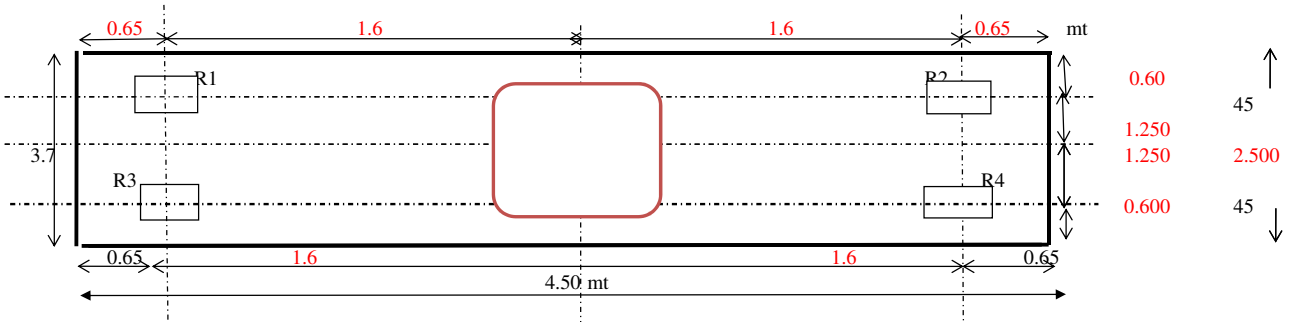
Preliminary Design of Single pier with open foundation supporting 8.5m deck.

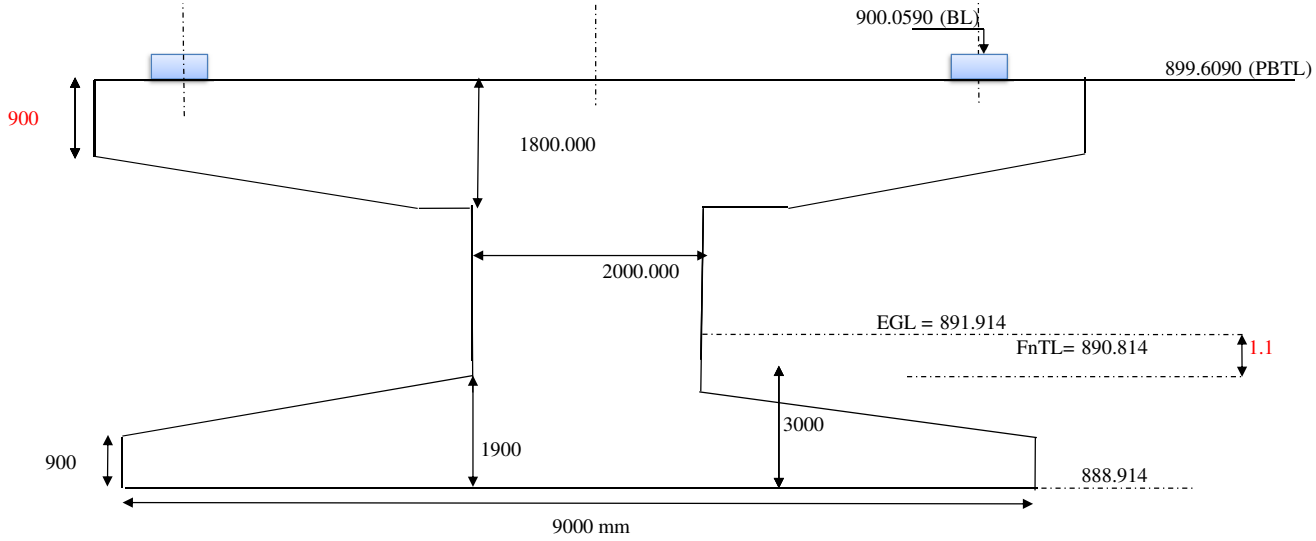
Design of Pier Substructure and Foundation for Piers between 45m and 45m Spans

The Substructure is proposed with single Rectangular Pier with Pier Cap.The Foundation is Open Foundation.The PTFE bearings are proposed on Pier Cap.
Pier Sustructure is analysed for load combinations as per IRC 6-2017 and Designed following IRC 112-2020 codal provisions
This Design note presents design of Pier substructure and foundation for piers supporting 45m+45m spans.

SCHEDULE OF LEVELS

Sl.No	PIER	FRL at edge of Median	EGL	Cross Slope	Superstructure depth +Wearing Coat	PBTL	Foundation top Level	Total height of Pier (m)
1	P2	902.540	891.914	2.50%	2.481	899.6003	890.814	11.7260





1) GENERAL DATA FOR DESIGN

Finished Road Level	*FRL*	=	***902.540***	m	
Existing ground level	*EGL*	=	***891.914***	m	
Pier Bottom level	*FnTL*	=	***890.814***	m	
Found^{n} Bottom Level	*FnBL*	=	***888.914***	m	
Bearing Level	BL	=	***900.059***	m	
Height of super structure at centre of median (LEFT Span)	45.00 m span	SSD =	***2.431***	m	(Excluding wearing coat)
Height of Super Structure at centre of median (RIGHT Span)	45.00 m span	SSD =	***2.431***	m	(Excluding wearing coat)

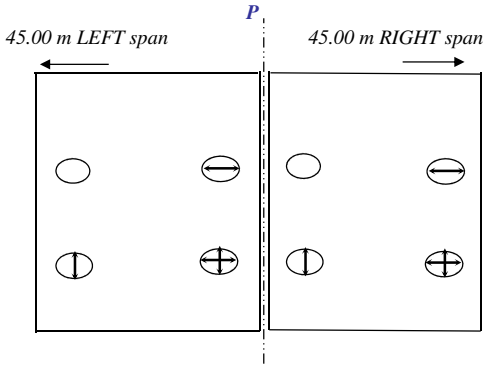
DATA FOR PIER DESIGN

Overall Span of the Bridge (Left Span)	*45.00 m span*	=	*45000*	*mm*	
Effective Span of the Bridge (Left Span)	*45.00 m span*	=	*42500*	*mm*	
Overall Span of the Bridge (Right Span)	*45.00 m span*	=	*45000*	*mm*	
Effective Span of the Bridge (Right Span)	*45.00 m span*	=	*42500*	*mm*	
Overall Width of Deck		=	*8500*	*mm*	
Width of Medain		=	*1000*	*mm*	
Overall Heigth of Substructure (From Bearing Level to Footing Top Level) =			***9245.000***	*mm*	
Width of pier at top (long)		=	2500	*mm*	
Length of pier at top (trans)			2000	*mm*	
Pier Cap Width in Long Dir^{n}.		=	***3700.000***	*mm*	
Pier Cap Length in Trans Dir^{n}.		=	***4500.000***	*mm*	
Straight Depth of Pier Cap		=	***1800.0***	*mm*	PTFE Bearing

Size of bearing for (LEFT Span)	45.00 m span	=	**600**	**x 600**	**x 150**	**2**	*Nos*
Size of bearing for (RIGHT Span)	45.00 m span	=	**600**	**x 600**	**x 150**	**2**	*Nos*
Size of Pedestals for (LEFT span)	45.00 m span	=	**900**	**x 900**	**x 300**	**2**	*Nos*
Size of Pedestals for (RIGHT span)	45.00 m span	=	**900**	**x 900**	**x 300**	**2**	*Nos*

Total straight Height of Pier (From Pier Cap bottom to Pier Bottom Level) = **6995** *mm* (*Max.Height*)

Width Of foundation	=	**9000**	*mm*
Length of foundation	=	**10000**	*mm*
Terminated level is considered below EGL =	=	**3000**	*mm*
Footing Bottom Level	=	**888.914**	*m*
Thickness of foundatin at face of peir	=	**1900**	*mm*
Thickness of foundatin at egde	=	**900**	*mm*
Thickness of Wearing coat	=	**50**	*mm*



Constants

Density of concrete	=	**25**	kN/m^3
Weight of wearing coat	=	**2**	kN/m^2
Grade of Concrete for Pier Cap,Pier	=	**M - 50**	*MPa.*
Grade of Concrete for Substructure	=	**M - 35**	*MPa.*
Grade of Steel (substructure)	=	**Fe - 550**	*MPa.*

AS PER IRC6:2017, TABLE B.2, PAGE NO 93, THE LOAD FACTORS IS AS UNDER

For Verification of Structural Strength

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*	*Seismic is Leading & VLL is accompanying*
1)	*SW =*	**1.35**	1.35	1.35
2)	*SIDL(W/o WC) =*	**1.35**	1.35	1.35
3)	*WC =*	**1.75**	1.75	1.75
4)	*VLL =*	**1.50**	1.15	0.2
5)	*BRAKING FORCE =*	**1.50**	*1.15*	0.2
6)	*WIND =*	**0.90**	*1.5*	-
7)	*Seismic =*	-	-	1.5

B.1) DEAD LOAD FROM SUPERSTRUCTURE(From STAAD)

Left Span 45,m ***Unfactored Loads***

	R1	*R2*
Self Weight	1319.10	1319.10
Crash Barrier+Median	179.70	179.70
WC	168.54	168.54
Total	***1667.34***	***1667.34***

Right Span- 45 m ***Unfactored Loads***

	R3	*R4*
DL	1319.10	1319.10
SIDL	179.70	179.70
WC	168.54	168.54
Total	***1667.34***	***1667.34***

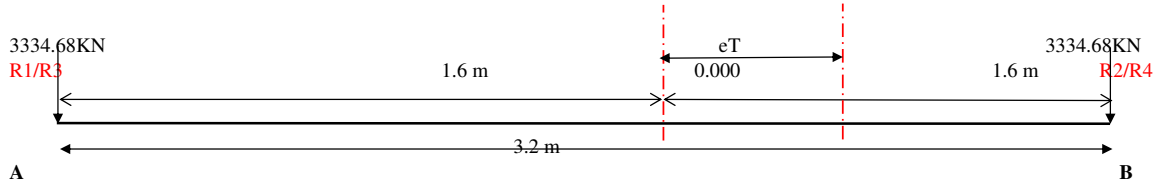
RESULTS FROM STAAD- 45.00 m LEFT span *Factored Loads*

	R1	R2
Self Weight	1780.79	1780.79
Crash Barrier+Median	242.60	242.60
WC	294.95	294.95
FPLL	0.00	0.00
TOTAL	**2318.33**	**2318.33**

RESULTS FROM STAAD- 45 m RIGHT span *Factored Loads*

	R3	R4
DL	1780.79	1780.79
SIDL	242.60	242.60
WC	294.95	294.95
FPLL	0.00	0.00
TOTAL	**2318.33**	**2318.33**

Cakculation of Transverse Moment due to Dead load



Cg of Loads from A	=		1.600	m
Cg of Loads from B	=		1.600	m
Eccentricity eT=	0.000	m		
MT=	0.00	KNm		(Unfactored)
MT=	0.00	KNm		(Factored)

Calcluation of Moment due to DL in Longitudinal Direction

45 m Right Span e_L = 1.250 m

45 m Left Span e_L = 1.250 m

Factored Longitudinal moment due dead load $M_{L\ (Factored)}$ = 5795.8 - 5795.81

= 0.0 kN-m

ML For Pier Cap Design=	0.00 (Factored)	ML For Pier Cap Design=	0.00 (Unfactored)
ML For Pier Design	0.00 (Factored)	ML For Pier Design	0.00 (Unfactored)

B.2) LIVE LOAD FROM SUPERSTRUCTURE

Following Vehicular Live loads are considered-

(i). 2 Class A vehicle
(ii). One 70RL Vehicle
(iii). One 70RN Vehicle

The variations of Live load combination is considered as per Table 2 of IRC 6-2017.
The reduction of longitudinal effect is considered as Cl:205 of IRC 6-2017

For 3 lanes Reduction in longitudinal effect = 10

Impact Factor : As per Cl 208 IRC : 6-2017
1) For Class A Vehicle,
2) For 70R Wheeled Vehicle

For 45.00m LEFT span	**L = 42.50 m**		For 45.00 m RIGHT span	**L = 42.50 m**	
L= Effective	= 9.28%	(Cl:208.2)	IF=4.5/(6+L)	= 9.28%	(Cl:208.2)
Span	= 9.28%	(Cl:208.2)	L= Effective Spa	= 9.28%	(Cl:208.2)

a) Vehicular Live Load from Staad pro.for 45.00 m LEFT Span (With impact Factor)

Eccentricity in longitudinal direction = 1.25 mt
For Four lanes 10 percent Reduction

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	735.80	423.80	662.22	381.42	**1043.64**	1.250	1304.55	0.430	449.28
2	70R	814.30	126.50	732.87	113.85	**846.72**	1.250	1058.40	1.170	990.43

b) Vehicular Live Load from Staad pro.for 45.00 m RIGHT Span (With impact Factor)

Summary of Reactions For Three Lanes: (From STADD Analysis)
For three lanes 10 percent Reduction
Eccentricity in longitudinal direction = 1.250 mt

Sl No	Vehicle case	R6(kN)	R7(kN)	R6(kN) Lane Reduction	R7(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	735.20	423.30	661.68	380.97	**1042.65**	1.250	1303.31	0.431	449.14
2	70R	813.60	127.20	732.24	114.48	**846.72**	1.250	1058.40	1.167	988.42

c) Vehicular Live Load from Staad pro.for 45.00 m LEFT Span (Without impact Factor)

Eccentricity in longitudinal direction = 1.25 mt

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	673.33	387.82	673.33	387.82	**1061.14**	1.250	1326.43	0.43	456.82
2	70R	745.16	115.76	670.65	104.18	**774.83**	1.250	968.54	1.17	906.34

d) Vehicular Live Load from Staad pro.for 45.00 m LEFT Span (Without impact Factor)

Sl No	Vehicle case	R6(kN)	R7(kN)	R6(kN) Lane Reduction	R7(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	672.78	387.36	672.78	387.36	**1060.14**	1.250	1325.17	0.43	456.67
2	70R	744.52	116.40	670.07	104.76	**774.83**	1.250	968.54	1.17	904.49

e) Vehicle on Both spans;
Summary of Reactions (From STADD Analysis)

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
1	2CA	194.78	76.22	200.67	78.53	175.30	68.60	180.60	70.68
2	70R	452.47	73.10	443.54	71.65	407.22	65.79	399.19	64.49

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
495.18	1.250	9.22	0.70	346.61
936.68	1.250	11.68	1.15	1081.81

f) Vehicle on Both span(Without impact Factor);

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction
1	2CA	178.24	69.75	183.63	71.86	178.24	69.75	183.63	71.86
2	70R	414.05	66.89	405.88	65.57	372.65	60.20	365.29	59.01

Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
503.48	1.250	629.36	0.70	352.42
857.15	1.250	1071.44	1.15	989.96

B.3 Braking Force (As per cl 211.2, IRC: 6- 2017)

Braking force is acts at 1.2 mt above road level

ML= HL x L.A

L.A = Lever Arm

Effective span (L) = 42.50 m

FRL = 902.540 m

1) For 45.00m LEFT span

Wearing coat = 0.05 m

Depth of super structure= 2.431 m

L.A = 2.481 + 1.2 = 3.68 m

Sl No	Vehicle case	1^{st},2^{nd} and 3^{rd}LANE in kN	3^{rd} LANE in kN =	1^{st} & 2^{nd} LANE(20%) in kN	3^{rd} LANE(10%) in kN	Total HL in kN	ML=HL x L.A in kNm
1	2CA	1108.000	1108.000	221.600	110.800	332.400	1223.564
2	70R	1000.000	0.000	200.000	0.000	200.000	736.200

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
28.790	14.395	166.200	83.10
17.322	8.661	100.000	50.00

2) For 45.00 m RIGHT span

Wearing coat = 0.05 m Effective span (L) = 42.5 m

Depth of super structure= 2.431 m FRL = 902.540 m

L.A = 2.481 + 1.2 = 3.68 m

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(5%) in kN	Total HL in kN	ML=HL x L.A in kNm
1	2CA	1108	1108.00	221.60	110.80	332.40	1223.56
2	70R	1000	0.00	200.00	0.00	200.00	736.20

Add Axial load(kN)	Add Axial	HL (kN) per	HL (kN) per
28.79	14.39	166.20	83.10
17.32	8.66	100.00	50.00

Specimen calculations:

Additional axial load at bearing level= 332.4x(2.481+1.2)/42.5 28.790 kN

B.4 Friction Force (Normal Case): As per Cl.211.5.1.1 IRC:6-2017

Fixed Bearings : Fh - μ (Rg + Rq) or (Fh/2) + μ (Rg + Rq)

Fh = Applied Horizontal Force Due to Braking Effect

μ = Co-efficent Friction 0.05 For Surface between PTFE and Steel

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

Free Bearings : μ(Rg+Rq)

μ = Co-efficent Friction 0.05

Rg = Reaction @ Free End due to Dead load

Rq = Reaction @ Free End due to Live load

For 45.00m LEFT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing	μ (Rg + Rq) per Bearing	μ (Rg) per Bearing
1	2CA	0.00	0.05	3334.68	1043.64	218.92	109.4580	83.367
2	70R	0.00	0.05	3334.68	846.72	209.07	104.5350	83.367
						218.92		

For 45.00 m RIGHT span (one Span loaded case) (With impact Factor): Horizontal Force @ Bearing Level

Sl No	Vehicle case	Fh	μ	Rg	Rq	F_h+μ (Rg + Rq) @ Fixed Bearing	F_h+ μ (Rg + Rq) per Bearing
1	2CA	332.400	0.050	3334.680	1042.650	551.27	275.633
2	70R	200.000	0.050	3334.680	846.720	409.07	204.535

B.6 Wind load calculation as per IRC 6:2017 Cl:209

Wind Speed at the Project Site 33 m/s

Avg Ht of the deck above EGL 11.626 m (ht of superstr+1m Crash barrier)

Type of Terrain — Since the Grade separator is inside the city with well developed Buildings.

	Terrain with Obstructions	
	Height	Pz
Upto	10	0.1905
	15	0.2305
	20	0.2650
	11.626 m	0.203

Pressure as per table 0.203 kN/sqm FRL 902.540

Pressure as per table, corresponds to basic wind speed of 33 m/s

Design wind pressure =(wind speed at site^2/33^2) x Wind pressure corresponding to 33 m/sec

Deisgn wind pressure = 0.2026137x(33^2/33^2= 0.203 kN/sqm

Design Pressure Pz= **0.203** kN/sqm GL 891.914

Wind Force in Transverse direction = Pz X A1 X G X Cd

G = gust factor = 2.00

Cd = drag coeff =

1.1 for Slab bridges with b/d>10
1.5 for Box/single beam b/d 2
1.3 for Box/single beam b/d> 6
2.25 for 2 or more Box/ beam b/d 2
1.95 for 2 or more Box/ beam b/d > 6
2.20 for single plate girder
2(1+c/20d) for multiple plate girders

C= Centre to centre distance of adjacent girders = 1.60 m d =

Cd =	1.425

Wind on Superstructure :

For 45.00m LEFT span

Wind Force in Transverse direction = Pz X A1 X G X Cd

Length of span from Centre to centre of Expansion Joint = 45 m

Effective Span = 42.5 m

Width of Deck = 8.5 m

Superstructure Depth 2.481 m

Total depth =(Superstucture Depth + Crash barrier height (1m)) SSD= 2.481 m, CBD= 1.00m 3.481 m

Area of Superstructure 3.481 x 45.000 **156.645**

Force in Transverse direction = Pz X A1 X G X Cd

FT = 0.203x156.645x2x1.425 **90.45** m^2

MT Bearing Level due to 45.00 m span

L.A = 3.481 /2 = 1.741 m

MT Bearing Level due to 45.00 m span **= 157 KNm**

MT Bearing Level / span **= 79 KNm**

Add^n axial load = MT/(Eff.Bearing Spacing 78.72/3.2 **24.599** kN

Horizontal Force @ Bearing level per span = **45.227** kN

Force in long dir^n = 0.25 times FT = **22.614** kN

Add^n axial load = **22.62/42.5** = **0.5** kN

For 45.00 m RIGHT span

Wind Force in Transverse direction = Pz X A1 X G X Cd

Length of span from Centre to centre of Expansion Joint = 45 m

Effective Span = L = 42.50 m

Width of Deck = 8.5 m

Superstructure Depth 2.481 m

Total depth SSD = 2.481 m, CBD= 1.000 m 3.481 m

Area of Superstructure = 3.481 x 45.000 **156.645**

Force in Transverse direction = Pz X A1 X G X Cd

FT = 0.203x45x2x1.425 **90.45** m^2

MT Bearing Level due to 45.00 m span

L.A = 3.481 /2 = 1.741 m

MT Bearing Level due to 45.00 m span **= 157 KNm**

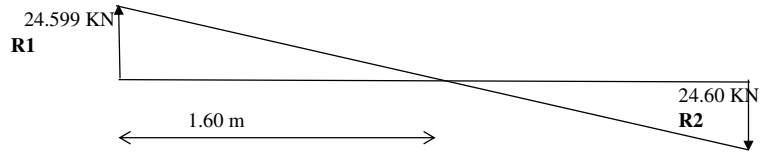
MT Bearing Level / span **= 79 KNm**

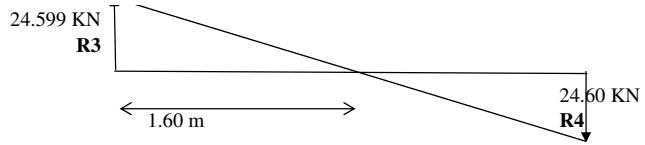
Add^n axial load = MT/(Eff.Bearing Spacing) = 78.72/3.2 **24.599** kN

Horizontal Force @ Bearing level per span= **45.227** kN

Force in long dir^n = 0.25 times FT = **22.614** kN

Add^n axial load = **22.62/42.5** = **0.53** kN





Wind Force on Vertical (+/-) **For 45.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Area of Superstructure (plan area) 45.0 x 8.5

A_3 = **382.500** m^2

CL = lift coeff = 0.750 for Slab/ box/ I girders and plate girders

Fv = 0.203x382.5x2x0.75 = **= 116.2KN**

Fv/ one side = = **= 58.1KN**

Vertical Force per Bearing = 58.125 / 2 = **= 29.1KN**

Wind Force on Vertical (+/-) **For 45.00 m span**

Fv = Pz X A3 X G X CL (As per IRC 6-2017,Cl:209.3.5)

A_3 = Superstructure (plan area) 45.0 x 8.5

A_3 = **382.5** m^2

CL = lift coeff = 0.750

Fv = 0.203x382.5x2x0.75 = **= 116.2KN** KN

Fv/ one side = **= 58.1KN**

Vertical Force per Bearing = 58.12 / 2 = **= 29.1KN**

Wind on Live Load :

For 45.00m LEFT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.481 m

Ht of vehicle considerded above Crash barrier= =3-1 2.0 m

Area of Superstructure 2 x 45.0 **= 90.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.481 = 4.481 m

FT = 0.203x90x2x1.2 = **43.76KN**

MT Bearing Level due to 45.00 m span **43.76KN**

L.A = 4.481 m

MT Bearing Level due to 45.00 m span

MT= 43.765 x 4.481 **= 196 KNm**

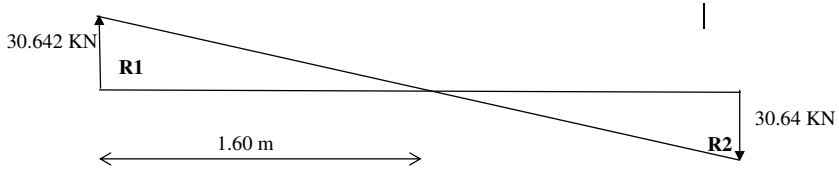
MT Bearing Level / span **= 98 KNm**

Add^n axial load = MT/(Eff.Bearing Spacing) = 98.06/3.2 = 30.6KN

Horizontal Force @ Bearing level per span = = 21.9KN

Force in long dir^n = 0.25 times FT = 10.9KN

Add^n axial load = **0.25x98.06/42.5 = 0.6KN**



For 45.00 m RIGHT span

Force in Transverse direction = Pz X A1 X G X Cd

Ht of super structure +Crash Barrier = 3.48 m

Ht of vehicle considerded above Crash barrier= 2.0 m

ea of Superstructure A1 = 2 x 45.0 **= 90.0m2**

Cd = 1.2

L.A = 2.000 /2 + 3.481 = 4.481 m

FT = 0.203x90x2x1.2 = **43.76KN**

MT Bearing Level due to 45.00 m span

L.A = 4.481 m

MT Bearing Level due to 45.00 m span

MT= 43.765 x 4.481 **= 196 KNm**

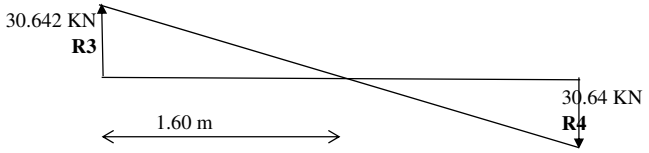
MT Bearing Level / span **= 98 KNm**

Add^n axial load = MT/(Eff.Bearing Spacing) = 98.06/3.2 = 30.6KN

Horizontal Force @ Bearing level per span = = 21.88KN

Force in long dir^n = 0.25 times FT = 10.94KN

Add^n axial load = **0.25x98.06/42.5 = 0.58KN**



Summary of wind force at bearing level :

Sl No	Load case	HT (kN)	HT / Bearing (kN)	HL (kN)	HL / Bearing (kN)	Vertical Force(kN) / One side of span	Vertical Force(kN) / Bearing
1	Wind on loaded structure from 45.00m span (One side of LEFT span)	67.11	33.55	16.8	8.39	114.5	57.24
2	Wind on Unloaded structure from 45.00m span (One side of LEFT span)	45.23	22.61	11.3	5.65	83.3	41.63
3	Wind on loaded structure from 45.00m span (One side of RIGHT span)	67.11	33.555	16.8	8.389	114.5	57.238
4	Wind on Unloaded structure from 45.00m span (One side of RIGHT span)	45.23	22.614	11.3	5.653	83.3	41.628

DESIGN OF PIER CAP:

Distance from Face of Beam to cg of load — a = 600.00 mm — No of Bearings on Cantilever **45.00 m span** = 1

Thickness of corbel//Pier beam at face — h = 1800.000 mm — Portion of Beam from LEFT

Effective depth of corbel/Pier beam — d' = 1706.500 mm — No of Bearings on Cantilever **45.00 m span** = 1

d = 1365.200 (0.8d') — Portion of Beam from RIGHT

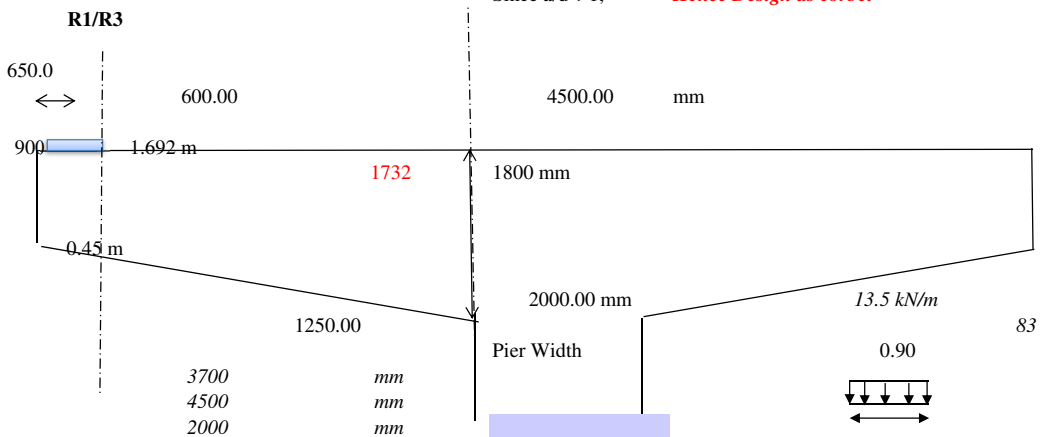
Thickness of Pier beam at end — S = 900.000 mm

Eff. width of beam — b = 3700.000 mm

Checks actual

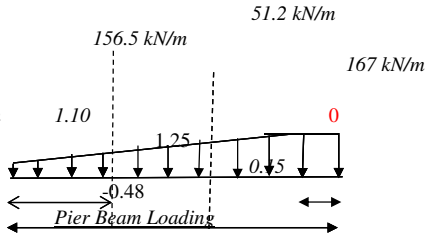
If a/d' <= 1.0 Design as a Corbel — a/d' = 0.352 — Vu/bd <= 0.15fc — 1.237 < 7.500 **safe**

Since a/d' >1, ***Hence Design as corbel***



Lever Arms w.r.t face of pier	
L.A3=	0.600 m
L.A1=	0.600 m

Face of Pedestal-1



Pier Beam width = 3700 mm

Total length of Pier beam = 4500 mm

Pier Width = 2000 mm

Summary of Forces on Pier Cap (Pier Beam) **(TABLE No -1)**

1) Forces on Pier Cap due to Dead load

Type of Loads		Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
		P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Dead Load from Superstructure w.r.t to face of Pier	R1	2318.33	0.00	1391.00	1667.34	0.00	1000.40	1667.34	0.00	1000.40
	R3	2318.33	0.00	1391.00	1667.34	0.00	1000.40	1667.34	0.00	1000.40

Dead Load from superstructure w.r.t to face of Pedestal-@ (R1 +R5)	R1+R3	4636.65	0.00	2086.49	3334.68	0.00	1500.61	3334.68	0.00	1500.61

2) Forces on Pier Cap due to Vehicular Live load

Type of Loads		Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
		P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
VLL (One Span) w.r.t face of Pier	R1	1099.31	1374.13	*659.58*	732.87	916.09	*439.72*	549.65	687.07	*329.79*
	R3	1098.36	1372.95	*659.02*	732.24	915.30	*439.34*	549.18	686.48	*329.51*
VLL (One Span) w.r.t face of Pedestal@	R1	1099.31	1374.13	494.69	732.87	916.09	329.79	549.65	687.07	*247.34*
VLL (Both Span) w.r.t face of Pier	R1	610.83	15.07	*366.50*	407.22	10.05	*244.33*	305.42	7.53	*183.25*
	R3	598.78	0.00	*359.27*	399.19	0.00	*239.51*	299.39	0.00	*179.63*
VLL (Both Span) w.r.t face of Pedestal-(R1+R5)		1209.61	15.07	544.33	407.22	10.05	183.25	305.42	7.53	137.44

3) Forces on Pier Cap due to Braking Force and Frictional Force

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Braking and Frictional Force at Bearing level (LEFT From 33.4m span)									
Braking force w.r.t face of Pier (R1)	21.59	369.42	12.96	14.39	246.28	8.64	10.80	184.71	6.48
Braking force w.r.t face of Pedestal@ (R1)	21.59	351.69	9.72	14.39	234.46	8.64	10.80	175.84	6.48
Braking and Frictional Force at Bearing level (RIGHT From 33.4m span)									
Braking force w.r.t face of Pier (R3)	21.59	930.26	12.96	14.39	620.17	8.64	10.80	465.13	6.48
Braking force w.r.t face of Pedestal@ (R3)	21.59	657.17	9.72	14.39	438.11	6.48	10.80	328.59	4.86
Centrifugal Force Due to Curvature effect									
Cerntrifugal Force at face of pier	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cerntrifugal Force at face of Pedestal@R1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.00*
Cerntrifugal Force w.r.t w.r.t 'd' from face of pier	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.00*

4) Force due to Self Weight of Pier Beam and Pedestal

Type of Loads	Loads for Factored Combination			Loads for Rare combination			Loads for Frequent combination		
	P (Shear) in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m	P in kN	ML (Torsion) in kN-m	B.M (MT) in kN-m
Force due to Self Weight of Pier Beam									
Pier Beam w.r .t face of Pier	210.73		*117.04*	156.09		*86.70*	156.09		*97.56*
Pier Beam w.r .t face of Pedestal	178.02		*87.92*	131.87	0.00	*65.13*	131.87	0.00	*65.13*

Force due to Self Weight of Pedestal									
Pedestal w.r.t to face of Pier @ (R1+R3)	16.40		9.84	12.15	0.00	7.29	12.15	0.00	7.29
Pedestal w.r.t to face of Pedestal-@ (R1+R3)	16.40		7.38	12.15	0.00	5.47	12.15	0.00	5.47
5) Forces due to Wind on Pier Cap									
Type of Loads	**Loads for Factored Combination**			**Loads for Rare combination**			**Loads for Frequent combination**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***	***P in kN***	***ML (Torsion) in kN-m***	***B.M (MT) in kN-m***
Wind Forces on Super structure									
Wind on Super Structure w.r.t face of Pier @ (R1+R3)	44.28	81.22	*324.86*	29.52	54.14	*216.58*	24.60	45.12	180.48
Wind on Super Structure w.r.t face of Pedestal-@ (R1+R3)	44.28	79.02	*316.07*	29.52	52.68	*210.71*	24.60	43.90	175.59
Wind Forces on Live Load									
Wind on Live Load w.r.t face of Pier @ (R1+R3)	55.16	66.28	*265.12*	36.77	44.19	176.75	30.64	36.82	147.29
Wind on Live Load w.r.t face of Pedestal-@ (R1+R3)	55.16	65.22	*260.87*	36.77	43.48	173.91	30.64	36.23	144.93
Vertical force due to Wind									
Verticle wind load per Bearing w.r.t face of Pier @ (R1+R3)	52.31	0.00	*31.39*	34.87	0.00	20.92	29.06	0.00	17.44
Verticle wind load per Bearing w.r.t face of Pedestal-@ (R1+R3)	52.31	0.00	23.54	34.87	0.00	15.69	29.06	0.00	13.08

Load Combinations:

Comb:-1 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL One Span Condition)

Comb:-2 DL+VLL (Braking,Centrifugal,Frictional Force)+Wind Load (VLL Both Span Condition)

Summary of Forces **(TABLE No -2)** **(Combination 1)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**6136.4**	**2451.89**	**4202.8**	**6103.7**	**2175.5**	**3286.7**
Rare Combination	**4351.35**	**1634.59**	**2957.40**	**4327.13**	**1450.36**	**2309.95**
Frequent Combination	**4147.68**	**1234.14**	**2787.13**	**4123.45**	**1095.78**	**2158.62**
Quasi Permanent Combination	**3502.92**	**0.00**	**2094.80**	**4831.07**	**0.00**	**2181.79**

Summary of Forces **(TABLE No -3)** **(Combination 2)**

Load Combination	**Pier Cap Forces w.r.t face of Pier**			**Pier Cap Forces w.r.t face of Pedestal @ (R1+R5)**		
	P (Shear) in kN	***ML (Torsion) in kN-m***	***B.M in kN-m***	***P (Shear) in kN***	***ML (Torsion) in kN-m***	***B.M in kN-m***
Factored Combination	**6246.7**	**1462.25**	**4269.0**	**6214.0**	**1168.2**	**3336.3**
Rare Combination	**4424.89**	**728.55**	**3001.53**	**4001.48**	**544.32**	**2163.41**
Frequent Combination	**4202.83**	**554.61**	**2820.22**	**3879.22**	**416.25**	**2048.71**

Quasi Permanent Combination	3502.92	0.00	2094.80	3478.70	0.00	1571.20

1) DESIGN OF PIER CAP

Grade of concrete = M50
Grade of steel = Fe550

Q = 0.133 fck (for Fe 550)
Q = 6.65 N/mm2

Design Moment = 4268.97 kNm
Effective Depth Reqd "deff" = $\frac{M}{Q \times B}$

deff reqd: = $\sqrt{\frac{4268.97 \times 1000000}{6.65 \times 3700}}$

= **416.53** mm < **1731.50** mm **O.K**

Clear Cover = **40** mm
Bar Dia = **25** mm

deff provided = 1800 - 40 - 16.0 = **1731.50**

Area of steel required (Ast) = (50*fck/fy)*(1-sqrt(1-(4.5*Mu/(fck*b*d^2))))*b*d/100

. ˙ . Ast reqd = 6475.16 mm^2
Ast reqd for launching Girder case = 0.00 mm^2
As1 = 490.9 mm^2
No of bars Reqd: = $\frac{6475.2}{490.9}$ = 13.19 → **18** Nos
Spacing of Bars = $\frac{3700}{18}$ = 205.56 mm

So provide **25** mm dia bars , **206** mm c/c spacing in **1** ***layer*** *of 18 Nos*
Ast Provided 8835.7 mm^2
OR 25 mm dia bars , 411 mm c/c spacing in 2 ***layers*** *of 9 Nos*
OR 25 mm dia bars , 617 mm c/c spacing in 3 ***layers*** *of 6 Nos*

Compression reinforcement **16** mm dia bars , ***of 18 Nos***

Check for Serviceability Limit State

1) Stress Check Calculation As per IRC 112-2020 (Quasi Permanent Combination-Table No B.3 of IRC6-2017)

Width of pier beam =	b=	3700
Thickness of Beam (mm)	h =	1800
Dia of main Bar (mm)		25
Effective Depth (deff) mm		1732
Ast pro (mm2)		8836
Max Moment (kN-m)		2094.80
Es (N/mm^2)		200000
Ecm (N/mm^2)		14403
m = α = Es/Ecm		13.89
X_U (mm) =		307.33
L.A (mm) =		1629.06
Stress in Steel (N/mm2)		145.53
Permissible stress in steel		440
Check for stree in steel		Hence OK
Stress in Concrete (N/mm2)		2.26

(Ref Table No-2 and 3)

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)
Stress in concrete= M/ (0.5.Xu.b.(L.A)

b X_u^2 /2 =m Ast (d-X_u)

a	1850.00
b	122690.41
c	-212438450
Xu 1 =	307.33
Xu 2=	-373.65

Permissible stress in concrete		18
Check for stree in concrete		**Hence OK**

2) Crack Width Calculation As per IRC 112-2020 (Quasi Permanent Combination-Table No B.3 of IRC6-2017)

(As per IRC 112-2020, Cl:12.3.4)

Dia of main Bar (mm)		25
Spacing of Bars (mm)		206
Max Moment (kN-m)		2094.80
Ast pro As (mm^2)		8835.73
C_{min} (mm)		40
a_{cr} (mm)		102.91
h (mm)		1800.00
d (mm)		1731.50
Es (N/mm^2)		200000
Ecm (N/mm^2)		14403
m = α = Es/Ecm		13.89
Xu (mm)		307.33
s_{sc} (N/mm^2)		145.53
k_t =		0.5
$f_{ct,eff}$ (N/mm^2)		3.5
$A_{c,eff}$ = b*$h_{c,eff}$ (mm^2)		633625.00
$h_{c,eff}$ least of	2.5 (h - d)	171.3
	(h - Xu/3)	497.6
	h / 2	900.0
$r_{P,eff}$ =		0.0139
e_{sm} - e_{cm} =		0.0000
		≥ 0.0004
e_{sm} - e_{cm} =		0.0004
IRC 112-2020	k1 =	0.8
	k2 =	0.5
Spacing	5(c + F/2) =	262.50
Case(i)	$S_{r.max}$ (mm)=	440.77
Case(ii)	$S_{r.max}$ (mm) =	1940.47
$S_{r.max}$ (mm) =		440.77
W_k (mm) =		0.192
Check for Crack Width		***Hence OK***

3) Stress Check for Provided Steel (Rare Combination) (As per Table No B.3 of IRC6-2017)

Width of pier beam =		b=	3700
Thickness of Beam (mm)		h =	1800
Dia of main Bar (mm)			25
Effective Depth (deff) mm			1732
Ast pro (mm2)			8836
Max Moment (kN-m)			3001.53
Es (N/mm^2)			200000

L.A= d - Xu/3

Stress in Steel = M/ (Ast xL.A)

Stress in concrete= M/ (0.5.Xu.b.(L.A)

a 1850.00

Ecm (N/mm^2)		14403
m = α = Es/Ecm		13.89
X_U (mm) =		307.33
L.A (mm) =		1629.06
Stress in Steel (N/mm2)		208.53
Permissible stress in steel		440
Check for stree in steel		**Hence OK**
Stress in Concrete (N/mm2)		3.24
Permissible stress in concrete		24
Check for stree in concrete		**Hence OK**

$b X_u^2/2 = m Ast (d-X_u)$

b	122690.41
c	-212438450
Xu 1 =	307.33
Xu 2=	-373.65

4) Deflection Check (By Freqent Combination-Table No B.3 of IRC6-2017)

For Cantiliver Slab *Deflection* = $P*l^3 / 3EI$

I = M.I = $bD^3/12$ = *1.7982E+12* mm2

Ec,eff = Ecm / (1+ ø)

Ecm = 35000 MPa (as per IRC-112, table-6.5) (Ref Table No-2 and 3)

P = 4202.83 *KN*

L = 0.60 *m*

As per IRC:112-2020, table-6.9, for RH-80%, & 28 days age loading

ø 1= 1.9 for 150

ø 2= 1.7 for 600

ø = **1.43** for 1211 2Ac/u = 1210.91

Ec,eff = 14403.29

deflection = *0.01 mm*

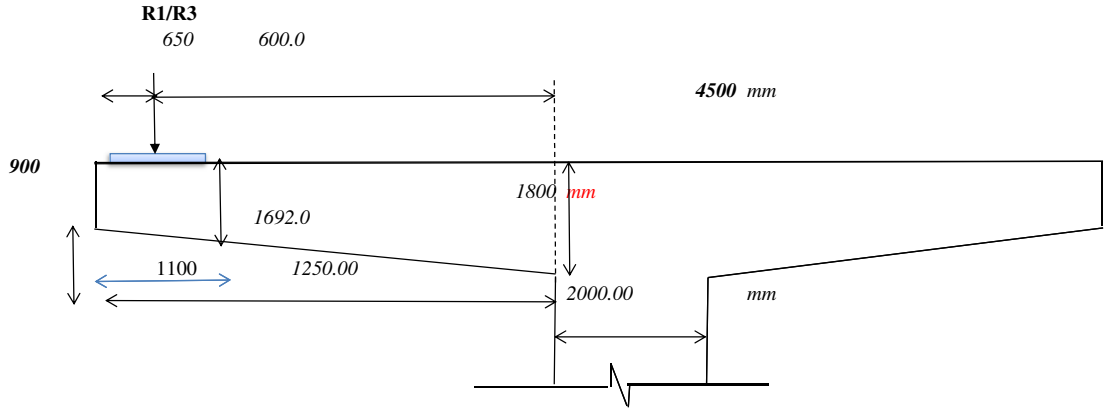
For cantiliver, as per IRC-112:2020, Cl:12.4.1(2)

δ = span / 300 2.00 *mm*

> *0.01* **Hence OK**

Check for Shear ***(As per Cl 10.3 of IRC 112-2020)***

pedestal size= *0.90* *x* *0.90* *x* *0.30* *mt*



Check for Shear at the face of Pedestal @ (R1+R3)

Widh of Pier Cap (B) = *3700 mm*

Depth at face of Pedestal (D)= *1692.0 mm*

Effective depth at face of Pedestal (d)= *1598.5 mm*

Total Shear force at face of Pedestal = *6214.0 KN*
Moment at face of Pedestal (MT) = *3336.3 KNm*

Effect of Torsion

According to IRC:112-2020, Cl:10.5.2.1 (1), to find the "Design Torsional Shear Force"

Shear stress ($t_{t,i}$)

$$\tau_{t,i} = \frac{T_{Ed}}{2A_k, t_{ef,i}}$$

T_{Ed}	=	2175.5 kN-m
A	=	6260400.0 mm2
U	=	10784.0 mm
$t_{ef,i}$	=	580.53 mm
Ak	=	3467211.3 mm2
Z_i	=	3700.0 mm

$t_{t,i}$ = 0.5 N/mm2

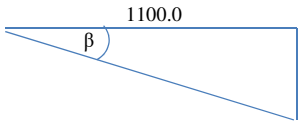
Design torsional shear force ($V_{Ed,i}$)

$V_{Ed,i}$ = $t_{t,i}t_{ef,i}Zi$
= 0.54 x 580.53 x 3700
= 1160801.18 N
= 1160.80 kN

Total shear force (V_{NS}) = 6,214.03 + 1,160.80
= 7374.83 kN

Shear due to depth of Varying section

(From IS 456-2000 Cl:40.1.1) Shear due to Beams of Varying depth = $\frac{Mu \times \tan\beta}{d}$



β = 0.62

$\tan\beta = \frac{792.00}{1100.00} = 0.72$

Mu = 3336.3 KNm

(From IS 456-2000 $\frac{Mu \times \tan\beta}{d}$ = 1502.75 KN

Resultant Shear Force = VEd-Mu x tan β/d = 5872.08 kN

Check for $V_{Rd.c}$ *(As per Cl 10.3.2 of IRC 112-2020)*

The design shear resistance $V_{Rd.c} \geq V_{Ed.}$

The design shear resistance of the member without shear reinforcement $V_{Rd.c}$ is given by:

$$V_{Rd.c} = \left[0.12K(80\rho_1 . f_{ck})^{0.33} + 0.15\sigma_{cp}\right] b_w.d$$

Subject to a minimum of $v_{Rd.c} = (v_{min} + 0.15\sigma_{cp})\, b_w.d$ **Eq. 10.1**

$K = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ **where d is depth in millimeters.** **Eq. 10.2**

and $v_{min} = 0.031K^{3/2} f_{ck}^{1/2}$, **Eq. 10.3**

σ_{cp} is limited to $0.2 f_{cd}$ (MPa) where $\sigma_{cp} = N_{Ed}/A_c < 0.2 f_{cd}$ **(MPa)**

$\rho_1 = \frac{A_{sl}}{b_w.d} \leq 0.02$ **(Fig.10.5)**

ρ1	=	0.001	
	=	0.001	
K	**=**	1.35	
N_{Ed}	**=**	0.00	KN
Ac	**=**	6260400.0	mm^2
σ_p	**=**	0.00	N/mm^2
$V_{Rd.c}$	**=**	**2934.11**	**kN**
V_{Ed}	=	5872.08	kN
$V_{Rd.c}$	<	V_{Ed}	

Hence Shear Reinforcement Required

As per A4.6.1, eq A4.5, IRC:112-2020,

V_{NS} = (ASW / S) * z * fywd * cot θ

f_{ywd} = 434.78 N/mm^2

Spacing (S) required = (ASW * z * fywd * cot θ / VNS

= 171 mm

Assuming

Hence proved **8 L** **Y - 16** **@ 130** **mm c/c**

Check for crushing of concrete (As per Cl 10.3.3.2 of IRC 112-2020)

At the face of Pedestal @ (R1+R3)

VRD.max = **αcw * bw * z * vi * fcd / (cotθ + tanθ)**

VRD.max = Crushing of compressive force for concrete

αcw =	1	
bw =	3700	mm
vi =	0.50	v=0.6*(1-fck/310)
fcd =	22.30	N/mm2

Z = 1438.650 mm

VRD.max = 29867.2 > 7117.0 kN

Hence Safe

Combined Check for Torsion and Shear (As per Cl 10.5.2 (4) of IRC 112-2020)

At the face of Pedestal @ (R1 +R3)

TRd.max = 2v * αcw * fcd * Ak * tef.i * sinθ * cosθ

TEd =	2175.54	kN-m	
TRd.max =			
VEd =	6214.03	kN	
VRd.max =	29867.21	kN	
v =	0.50		
TRd.max =			
Ak =	3467211.26	mm2	$(b-t_{ef,i}) \times (D-t_{ef,i})$
A=	6260400.00	mm2	
u =	10784.00	mm	
tef.i =	580.53	mm	
TRd.max =	22580.79	kN-m	

(TEd / TRd.max) + (VEd / VRd.max) ≤ 1.0 = 0.304

Hence Safe

Torsional Reinforcement (As per Cl 10.5.2 (5) of IRC 112-2020)

At the face of Pedestal @ (R1+R3)

Ak =	3.47	m2
T_{ed} =	2175.54	kN-m
u_k =	8.46	m
fyd =	478.26	N/mm2

$$\Sigma asl = \frac{T_{Ed} * \cot\theta * uk}{2A_k * fyd}$$

$$\Sigma asl = \frac{2{,}175.54 \times \cot(1) \times 8.46}{2 \times 3.47 \times 47{,}82{,}60{,}869.57}$$

0.0056 m2

5550.84 mm2

Required Longitudinal reinforcement will be distributed on 4 faces

Ast per face = 1387.710315

Hence Provide **Y - 20** **9 Nos**

Summary of Pier Cap Design:

1	*pier cap size =*	***4500 x***	***3700 x***	**1800 /**	**900.0**	***mm***		
2	*Grade of concrete =*		***M - 50***					
3	*Grade of steel =*		***Fe - 550***					
4	Tension Reinforcement in Transverse Direction =		**25**	**18 Nos**	**in One layer**	**or**	**9 Nos**	**in Two layers**
4a	Compression Reinforcement in Transverse Direction =		**Y 16**	**18 Nos**				
5	*Vertical stirrups =*		**8 L**	***- Y 16***	**130 c/c**	**in Trasverse direction**		
6	*Torsional Reinforcement*		**Y 20**	**9 Nos**	**on either side of Pier beam in Transverse Direction**			

3) DESIGN OF PIER

Forces at Base of the pier and Foundation bottom:

i) Vehicle on one span for 45.00 m LEFT Span) (Without impact Factor)

Sl No	Vehicle case	R1(kN)	R2(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	673.33	387.82	673.33	387.82	1061.14	1.25	1326.43	0.43	456.82
2	70R	745.16	115.76	670.65	104.18	774.83	1.25	968.54	1.17	906.34

ii) Vehicle on one span for 45.00 m RIGHT Span) (Without impact Factor)

Sl No	Vehicle case	R6(kN)	R7(kN)	R6(kN) Lane Reduction	R7(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)	eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1	2CA	672.78	387.36	672.78	387.36	1060.14	1.25	1325.17	0.43	456.67
2	70R	744.52	116.40	670.07	104.76	774.83	1.25	968.54	1.17	904.49

iii) Vehicle on Both Spans(without imact factor):

Sl No	Vehicle case	R1(kN)	R2(kN)	R3(kN)	R4(kN)	R1(kN) Lane Reduction	R2(kN) Lane Reduction	R3(kN) Lane Reduction	R4(kN) Lane Reduction	Total reaction (kN)(Lane Reduction)
1	2CA	178.24	69.75	183.63	71.86	175.30	68.60	180.60	70.68	495.18
2	70R	414.05	66.89	405.88	65.57	407.22	65.79	399.19	64.49	936.68

eL (mt)	ML (kNm)	eT (mt)	MT (kNm)
1.3	9.225	0.700	346.61
1.3	11.677	1.155	1081.81

iv A)Braking force from 45.00 m LEFT Span

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(10%) in kN	Total HL in kN	HL per Trestle (kN)	L.A For Pier Base
1	2CA	1108.00	1108.00	221.60	110.80	332.40	166.20	9.25
2	70R	1000.00	0.00	200.00	0.00	200.00	100.00	9.25

ML @ pier base	LA for Found^{n}	ML @ Found^{n}	Add Axial load(kN)
1536.52	11.15	1852.30	36.153
924.50	11.15	1114.50	21.753

iv B)Braking force from 45.00 m RIGHT Span

Sl No	Vehicle case	1st,2nd and 3rdLANE in kN	3rd LANE in kN	1st & 2nd LANE(20%) in kN	3rd LANE(10%) in kN	Total HL in kN	HL per Trestle (kN)	L.A For Pier Base
1	2CA	1108.00	1108.00	221.60	110.80	332.40	166.20	9.25
2	70R	1000.00	0.00	200.00	0.00	200.00	100.00	9.25

ML @ pier base	LA for Foundn Bottom	ML @ Foundn base	Add Axial load(kN)
1536.52	11.15	1852.30	36.153
924.50	11.15	1114.50	21.753

iv A)Longitudinal Effect:(Frictional force) (From 30m LEFT span)

(one Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing
1	2CA	0.00	0.05	3334.68	1043.64	218.92
2	70R	0.00	0.05	3334.68	846.72	209.07
						0.05

L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base	μ Rg
9.25	2023.88	11.15	2439.82	166.734
9.25	1932.85	11.15	2330.09	166.734

B)Longitudinal Effect:(Frictional force) (From 33.4m LEFT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (Single Span)

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	μ (Rg + Rq) @ Free Bearing	L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base
1	2CA	0.00	0.05	3334.68	247.99	179.13	9.25	1656.09	11.15	1996.44
2	70R	0.00	0.05	3334.68	432.85	188.38	9.25	1741.54	11.15	2099.46

B)Longitudinal Effect:(Frictional force) (From 33.4m RIGHT span)

(One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing
1	2CA	332.40	0.05	3334.68	1042.65	551.27
2	70R	200.00	0.05	3334.68	846.72	409.07

L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base	μ Rg
9.25	5096.46	11.15	6143.87	166.734
9.25	3781.85	11.15	4559.09	166.734

C)Longitudinal Effect:(Frictional force) (From 30m RIGHT span)

(Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh	μ	Rg / one side of span	Rq (one side of span)	Fh+μ (Rg + Rq) @ Fixed Bearing	L.A For Pier Base	ML @ pier base	LA for Found^{n} Bottom	ML @ Found^{n} base
2	2CA	332.40	0.05	3334.68	255.49	511.91	9.25	4732.60	11.15	5705.22
3	70R	200.00	0.05	3334.68	424.30	387.95	9.25	3586.59	11.15	4323.69

v) SELF WEIGHT OF PIER AND PIER SUBSTRUCTURE:

Pedastal size= 0.2430 m^3 Height of pier= 6.995 mt

No of pedastal= 4.0

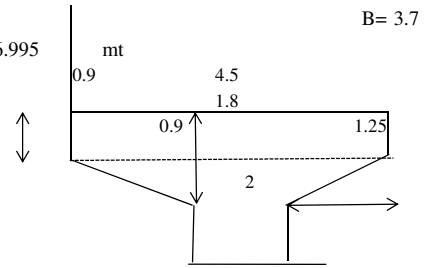
Total sw of pedastal= 24.3 kN

sw of pier beam = 645.2 kN

Area of pier = 5.00 m^2

sw of pier = **874.4** kN

Total sw = ***1543.9*** kN



vi) Wind Force

Wind on Pier Beam :

Width of Pier Cap 3.70 *m* *(b)* *t/b =* 1.22

Height of Pier Cap 1.80 *m* *(h)* *h/b =* 0.49

Length of Pier Cap 4.50 *m* *(t)*

Cd 0.844

Force in Transverse direction = Pz X A1 X G X Cd

A1 = 3.70 *m X* 1.80 *m =* 6.66 *sqm*

Ft = 0.203 *X* 6.66 *X* 2 *X* 0.844

2.28 *kN*

Force in long dirn = 25% *of F transverse =* 0.6 *kN*

Wind on Pier :

Width of Pier 2.5 *m* *(b)* *t/b =* 0.80

Height of Pier 6.4950 *m* *(h)* *h/b =* 2.60

Length of Pier 2 m (t)
Cd value 1.29
Force in Transverse direction = Pz X A1 X G X Cd
A1 = 2.50 m X 6.495 m = 16.2375 sqm
Ft = 0.203 X 16.2375 X 2 X 1.285
8.5 kN

Force in long dirn = 25% of F transverse = 2.1 kN

vii) Summary of Wind Load

Wind Force due to DL@ Bearing level	*Lever Arm in mt*	*Transeverse dirction*	*longitudinal dirction*	
Wind force Horizontal due to 45.00 m Left span		45.227	11.31	
Wind force Horizontal due to 45.00 m Right span span		45.227	11.31	
Moment at base of pier due to 45.00 m Left span	9.245	418.13	104.53	
Moment at base of pier due to 45.00 m Right span	9.25	418.13	104.53	
Moment at base of foundation due to 45.00 m Left span	11.15	504.06	126.01	
Moment at base of foundation due to 45.00 m Right span	11.15	504.06	126.01	
Total Horizontal Wind force		90.5	22.6	kN
Total Moment at base of pier		836.3	209.1	kNm
Total Moment at base of foundn	11.145	1008.1	252.0	kNm
Wind on pier Cap		***FT***	***FL***	
Wind force Horizontal		2.3	0.6	kN
Moment at base of pier	7.895	18.0	4.5	kNm
Moment at base of foundn	9.795	22.3	5.6	kNm
Wind on pier		***FT***	***FL***	
Wind force Horizontal	m	8.5	2.1	kN
Moment at base of pier	3.748	31.7	7.9	kNm
Moment at base of foundn	5.648	47.8	11.9	kNm
Total wind load on DL only		***FT***	***FL***	
Wind force Horizontal		101.2	25.3	kN
Moment at base of pier		885.9	221.5	kNm
Moment at base of foundn		1078.2	269.5	kNm
Wind due to LL at bearing level		***FT***	***FL***	
Wind force Horizontal due to 45.00 m span		21.9	5.47	
Wind force Horizontal due to 45.00 m span		21.9	5.47	
Moment at base of pier due to 45.00 m span	9.245	202.30	50.58	
Moment at base of pier due to 45.00 m span	9.245	202.30	50.58	
Moment at base of foundation due to 45.00 m span	11.145	243.88	60.97	
Moment at base of foundation due to 45.00 m span	11.145	243.88	60.97	
Total Horizontal Wind force		43.8	10.9	
Total Moment at base of pier		404.6	101.2	kNm
Total Moment at base of foundn		487.8	121.9	kNm

Wind force Vertical in kN	*(From Both spans)*		345.200	kN

ix) Seismic Analysis of Pier Sub Structure:

The seismic analysis is carried out as per the IRC: 6 – 2017 (Cl:219).

Feq = Ah x (Dead Load + Appropriate live load)
Where,
Ah = Horizontal seismic co – efficient
AR = Z.I / 2.R x Sa / g

Z = zone factor =	*0.1*	***(Zone – II)***	(Table-16 of IRC 6-2017)	
R =	*2.5*	(Table-20 of IRC 6-2017)		
I =	*1.2*	(Table-19 of IRC 6-2017)		
Dead Load Rxn =			*6669.36*	***kN***
VLL Rxn =	*20%*	*936.68*	*187.34*	***kN***
Total =			6856.6968	***kN***

As Per IRC:6- 2017 *(Annexure-D)*
T=2√W/(1000F)
$WL^3 / 3EI$ = 1.0

W=	*259.537*	***kN***
T=	*0.325*	***Sec***
Sa /g =	*3.076*	

T = *0.33* *sec*
Sa /g = 2.500

*Ah = 0.1*1.2*2.50/(2*2.5)* ***0.060***

l = Height of pier = *9245* *mm*
Ecm = *35000.0* *N/mm^2*

$$I_{gr} = \frac{b \times d3}{12}$$

Igr = 2604166666667 *mm^4*
I_{eff} = *1.95313E+12* *mm^4*
(0.75 x Igr)

Ecm = 35000 MPa (as per IRC-112, table-6.5)

Ec,eff = 35000.00 MPa 2Ac/u = 1111.11

i) Longitudinal direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Total Seismic load (Long-HL)**	
1	DL	6669.36	**400.16**	
2	Pier cap	645.19	38.71	
3	pedastals	24.30	1.46	
4	Pier	874.38	52.46	

ii) Transeverse direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Trans-HT)**	
1	DL	6669.36	**400.16**	
2	Pier cap	645.19	**38.71**	
3	pedastals	24.30	**1.46**	
4	Pier	874.38	**52.46**	

iii) Vertical direction:(Dead Loads)

Sl No	Component	Total vertical Load in kN	**Seismic load (Vertical-Vs)**	
1	DL	6669.36	**266.77**	
2	Pier cap	645.19	**25.81**	
3	pedastals	24.30	**0.97**	
4	Pier	874.38	**34.98**	

Seismic in Longitudinal Direction due to 45.00 m span						**Total ML @ pier base**	**Total ML @ Footing bottom**
Component	**HL**	LA w.r.to pier base	**ML @ pier base**	LA w.r.to pier base	**ML @ Footing bottom x 1.35**		
DL	400.16	10.4605	4185.89	12.3605	6677.37	**4185.89**	**6677.4**
Pier cap	38.71	7.8950	305.63	9.7950	511.89	**305.63**	**511.9**
pedastals	1.46	8.9450	13.04	10.8450	21.35	**13.04**	**21.3**
Pier	52.46	3.4975	183.49	5.3975	382.27	**183.49**	**382.3**

Seismic Transverse Direction due to 45.00 m span						**Total MT @ pier base**	**Total MT @ Footing bottom**
Component	**HT**	LA w.r.to pier base	**MT @ pier base**	LA w.r.to pier base	**MT @ Footing bottom x 1.35**		
DL	400.16	10.461	4185.89	12.36	6677.37	**4185.89**	**6677.4**
Pier cap	38.71	7.895	305.63	9.80	511.89	**305.63**	**511.9**
pedastals	1.46	8.945	13.04	10.85	21.35	**13.04**	**21.3**
Pier	52.46	3.498	183.49	5.40	382.27	**183.49**	**382.3**

Note: ***1.35*** For design of foundation, the seismic loads should be taken as 1.35 times the forces transmitted to it by concrete substructure.(219.8 of IRC 6-2017)

iv) Vehicle on one span(Without impact Factor) Seismic case: for 45.00 m LEFT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
1	2CA	**443.200**	**0.000**	**26.592**	9.245	**245.84**	**91.36**
2	70R	**160.000**	**0.000**	**9.600**	9.245	**88.75**	**181.27**

LA w.r.to Found^{n} Bottom	**MT (kNm) Footing bottom (due to seismic) x 1.35**	**Total MT @ Footing Base**	**ML due toVLL Eccentricity (kN-m)**
11.145	**400.10**	**491.46**	**265.29**
11.145	**144.44**	**325.71**	**193.71**

v) Vehicle on one span(Without impact Factor) Seismic case: for 45.00 m RIGHT Span

Sl No	Vehicle case	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	lever arm w.r t.pier base	**MT (kNm) pier base due to seismic**	**MT due to VLL Eccentricity**
1	2CA	**443.20**	**0.000**	**26.592**	9.245	**245.84**	**91.33**
2	70R	**160.00**	**0.000**	**9.600**	9.245	**88.75**	**180.90**

LA w.r.to Found^{n} Bottom	**MT (kNm) Footing bottom due to seismic x 1.35**	**Total MT @ Footing Base**	**ML due to VLL Eccentricity (kN-m)**
11.145	**400.10**	**491.43**	**265.03**
11.145	**144.44**	**325.34**	**193.71**

vi) Vehicle on Both Span (without imact factor):

Sl No	**Vehicle case**	**Seismic load (Vertical-V_s)**	**Seismic load (Long-HL)**	**Seismic load (Trans-HT)**	L Arm W.r t.pier base	**MT (kNm) pier base due to seismic**	**MT Due toVLL Eccentricity**
1	2CA	**443.20**	**0.000**	**26.59**	9.245	245.843	**69.32**
2	70R	**160.00**	**0.000**	**9.60**	9.245	88.752	**216.36**

LA W.r t.Found Bottom	**MT (kNm) Footing bottom due to seismic x 1.35**	**ML Due to VLL Eccentricity**
11.145	**400.10**	**1.845**
11.145	**144.44**	**2.335**

vi)Braking force(seismic case): 45.00 m LEFT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
1	2CA	1108.0	1108.0	221.6	55.4	203.9	4.80	**27.7**	9.25
2	70R	1000.0	0.0	200.0	0.0	147.2	3.46	**20.0**	9.25

LA at footing bottom	**ML @ Pier bottom**	**ML @ Footing bottom**
11.145	**256.09**	**308.72**
11.145	**184.90**	**222.90**

v)Braking force(seismic case): 45.00 m RIGHT Span

Sl No	Vehicle case	1st & 2nd LANE in kN	3rd & 4th LANE in kN	HL in 1st & 2nd LANE(20%) in kN	HL in 3rd & 4th LANE(5%) in kN	ML=HL x 0.2 x L.A in kNm	Add Axial load(kN)	**HL per Trestle x 0.20 in kN**	LA at pier base
1	2CA	1108.0	1108.0	221.6	55.4	203.9	4.80	**27.7**	9.25
2	70R	1000.0	0.0	200.0	0.0	147.2	3.46	**20.0**	9.25

LA at footing bottom	**ML @ Pier bottom**	**ML @ Footing bottom**
11.145	**256.09**	**308.72**
11.145	**184.90**	**222.90**

viA)Frictional (seismic case): 45.00 m LEFT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2017)

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
1	2CA	0.0	0.05	3334.7	208.7	**177.2**	**166.73**	9.245
2	70R	0.0	0.05	3334.7	169.3	**175.2**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	**ML @ Footing bottom**
1637.9	11.145	**1974.6**
1619.7	11.145	**1952.6**

B)Frictional force(seismic case): 45.00 m Left Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl (seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2017)

Sl No	Vehicle case	**Fh x 0.2**	**μ**	**Rg / one side of span**	**Rq (one side of span)**	**μ (Rg + Rq) @ Free Bearing**	**μ (Rg)**	L.A For Pier Base
1	2CA	0.0	0.05	3334.7	248.0	**179.1**	**166.73**	9.245
2	70R	0.0	0.05	3334.7	432.9	**188.4**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	**ML @ Footing bottom**
1656.1	11.145	**1996.4**
1741.5	11.145	**2099.5**

C)Frictional force(seismic case): 45.00 m RIGHT Span

One Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

Sl No	Vehicle case	Fh x 0.2	**μ**	**Rg / one side of span**	**Rq / one side of span x 0.2**	**Fh+μ (Rg + Rq) @ Fixed Bearing**	**μ (Rg)**	L.A For Pier Base
1	2CA	66.5	0.05	3334.7	208.5	**243.6**	**166.73**	9.245
2	70R	40.0	0.05	3334.7	169.3	**215.2**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	**ML @ Footing bottom**
2252.5	11.145	**2715.4**
1989.5	11.145	**2398.4**

D)Frictional force(seismic case): 45.00 m RIGHT Span

Both Span loaded case(Without impact Factor): Horizontal Force @ Bearing Levl

(seismic due to VLL is not considered in the direction of traffic (longitudinal direction) as per IRC 6-2017)

Sl No	Vehicle case	Fh x 0.2	μ	Rg / one side of span	Rq / one side of span x 0.2	Fh+μ (Rg + Rq) @ Fixed Bearing	μ (Rg)	L.A For Pier Base
1	2CA	66.5	0.05	3334.7	51.1	**235.8**	**166.73**	9.245
2	70R	40.0	0.05	3334.7	84.9	**211.0**	**166.73**	9.245

ML @ pier base	LA w.r.to Footing Bottom	ML @ Footing bottom
2179.7	11.145	**2627.6**
1950.5	11.145	**2351.3**

DESIGN OF PIER:

A). PIER LOAD COMBINATIONS

C1 to C4 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF)*

C5 to C8 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)*

C9 to C12 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C13 to C16 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*

C17 = *DL+SW+WIND ON UNLOADED STURCTURE*

The Pier section is designed as a rectangular section subjected to axial force and bending using SP-16, Design Aids For IS 456. The results are tabulated below:-

Load Factors as per IRC 6-2017 Table B.2

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying
1)	SW =	1.35	1.35
2)	SIDL(W/o WC) =	1.35	1.35
3)	WC =	1.75	1.75
4)	VLL =	1.5	1.15
5)	BRAKING FORCE =	1.5	1.15
6)	WIND =	0.9	1.5
7)	Seismic =	1.5	-

i) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm
C1	13314.14	12290.86	1846.69
C2	12863.07	9760.61	2520.98
C5	12465.19	9941.21	1681.38
C6	13105.85	8332.56	2784.19
C9	13137.21	9684.33	2461.12
C10	12791.38	7911.54	2978.08
C13	12486.35	7882.93	2334.39
C14	12977.52	6649.63	3179.87
C17	11640.10	979.47	332.22

ii) Seismic Combinations (Factored Loads) (As per Cl:219.4 of IRC 6-2017))

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*

C2 to C5 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)

C6 to C9 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

Combinations	P in kN	M_{L1} in kNm	M_{T1} in kNm
C1	12343.10	8971.45	2381.52

Seismic Forces in Transverse Direction

Combinations	P in kN	M_{L2} in kNm	M_{T2} in kNm
C2	13016.54	8198.42	7537.88
C3	12588.30	7696.67	7437.10
C8	13025.17	8122.13	7504.81
C9	12593.49	7836.06	7489.74

PIER LOAD COMBINATIONS (QUASI PERMANENT COMBINATION-Table No B.3 of IRC6-2017)

(PARTIAL SAFETY FACTOR TAKEN AS PER IRC:6,2017, TABLE NO 3.3)

Sl Nos	*Loads*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*
1)	*SW =*	***1.00***	1
2)	*SIDL(W/o WC) =*	***1.00***	1
3)	*WC =*	***1.00***	1
4)	*VLL =*	***0.00***	0
5)	*BRAKING FORCE =*	***0.00***	*0*
6)	*WIND =*	***0.00***	*0*
7)	*Seismic =*	-	-

COMB	P in kN	ML in kNm	MT in kNm	Design BM = $\sqrt{(ML^2+MT^2)}$
C1	8213.22	1541.46	0.00	1541.46

Check for Slenderness Ratio

Size of Pier 2500.000 x 2000.000 *mm*

Clear cover = 40.00 *mm*
Grade of Concrete = M - 50
Grade of Steel = Fe - 550

As per IRC:112-2020, The minimum Ast for Pier is as follows,
1). (Length / radius of gyration) < 12 is "Pedestal Column"
2). (Length / radius of gyration) > 12 is "Other Column"

Radius of Gyration (Rg) = Sqrt(I/A)
Rg = 722

I = 2.60417E+12 mm4
A = 5000000 mm2

Length of pier (Le) =		9679	*Effective lengthas per IRC:112-2020,Table 11.1,pg no 114, = l0*1.3*
Slenderness ratio	L / Rg =	13.41	**HENCE IT IS 'OTHER COLUMN'**

As per 11.2.2 of IRC 112-2020,Effective Length of Pier

(1) For compression members in regular frames, the effective length l_e is determined in the following way:

Braced Members:

$$l_e = 0.5 l_o \sqrt{\left(1+\frac{k_1}{0.45+k_1}\right) x \left(1+\frac{k_2}{0.45+k_2}\right)} \qquad \text{Eq.11.2}$$

Unbraced members:

$$l_e = l_o \; x \max of \left\{ \sqrt{\left(1+10.\frac{k_1.k_2}{k_1+k_2}\right)} \; ; \left(1+\frac{k_1}{1+k_1}\right) x \left(1+\frac{k_2}{1+k_2}\right) \right\} \qquad \text{Eq.11.3}$$

$\sqrt{1+\frac{10.K1.K2}{K1+K2}}$ = 1.22

$1+ K1/(1+K1) \times (1+ K2/(1+K2)$ = 1.190

l_o = 7445 mm

l_e = 9.12 m

Limiting Slenderness ratio as per IRC:112-2020, Cl:11.2.1(2),

Limiting Slenderness ratio as per IRC:112-2020, Cl:11.2.1(2)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

N_{Ed}=	13314.14	kN			
Ø ef=	φ(∞,to).M_{oEqp}/M_{oEd}				
φ(∞,to) =	*1.756*	*(As per IRC 112-2020,A2.5)*			
Mo_{Eqp} =	*1541.46*	KNm			
Mo_{ED} =	*12290.86*	KNm	Ac=	5000000	mm^2
Ø ef=	0.220		h= 2.Ac /U =	1111.1	mm
A=	0.958		fcd=	22.33	N/mm^2
w=	0.406		n=	0.12	
n=	0.12				
B=	1.346				
C=	0.7				
λ_{lim} =	52.29	>	9.12		

Hence OK

Limiting Slenderness ratio as per IRC:112-2020, Cl:11.2.1(2) (Direct Calculation)

λ_{lim} = 20.A.B.C / sqrt(n)

n= N_{Ed} / (Ac*fcd)

A= 0.70

Second order effects may be ignored if the slenderness ratio λ based on l_e as per Clause 11.2.2 is less than a certain value λ_{lim} as per Eq.11.1.

$$\lambda_{lim} = 20.A.B.C / \sqrt{n} \qquad \text{Eq.11.1}$$

where

A = $1/(1+0.2\phi_{ef})$

ϕ_{ef} *is effective creep ratio.*

$\phi_{ef} = \phi(\infty, t_o).\frac{M_{oEqp}}{M_{oEd}}$

M_{oEqp} *= First order B.M. in quasi-permanent load combination in SLS.*

M_{oEd} *= First order B.M. in design load combination in U.L.S.*

B = $\sqrt{1+2\omega}$

C = $1.7 - r_m$

ω = $A_s f_{yd} / (A_c f_{cd})$ *mechanical reinforcement ratio.*

A_s = *is the total area of longitudinal reinforcement.*

n = $N_{Ed} / (A_c f_{cd})$ *relative normal force*

r_m = M_{01} / M_{02} *moment ratio*

M_{01}, M_{02} *are the first order end moments at two ends of member as calculated from the analysis of structure, where* $|M_{02}| \geq |M_{01}|$.

If the end moments M_{01} & M_{02} *give tension on the same side,* r_m *should be taken positive (i.e.* $C \leq 1.7$*), otherwise negative (i.e.* $C > 1.7$*).*

In the following cases, r_m *should be taken as 1.0 (i.e.* $C = 0.7$*):*

- For unbraced members in general.
- For braced members in which the first order moments arise

predominantly from imperfections or transverse loading.

B=	1.10		
C=	0.70		
Ac=	5000000 mm2		
fcd=	22.33 N/mm2	**(α*fck/λ_m)**	*cl:6.4.2.8(1)*
N_{Ed}=	13314.14 kN		
n=	0.12		
λ_{lim} =	31.22		
>	9.12	**Hence OK**	

Design of Vertical Reinforcement

Check for design of Bi-axial Column (For Rectangular column)

As per 8.3.2(4)of IRC 112-2020, Pg no 75
For Rectangular column,

$$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{a} + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^{a} \le 1 \qquad \text{Eq. 8.3}$$

where
M_{Edx}, M_{Edy} Design moment around the respective axis, including nominal 2nd order moments.
M_{Rdx}, M_{Rdy} Moment resistance in the respective direction
Exponent as follows;
- for circular and elliptical cross-sections: $\alpha = 2$
- for rectangular cross-sections:

N_{Ed}/N_{Rd}	0.1	0.7	1.0
α =	1.0	1.5	2.0

With linear interpolation for intermediate values.
N_{Ed}= design value of axial force.
$N_{Rd} = A_c f_{cd} + A_s f_{yd}$ design axial resistance of section.

Size of Pier = 2000 x 2500.00

Combinations	**Normal Combination**			**Seismic Longitudinal**	**Seismic Transverse**	As per SP-16, Cl 3.3, Pg no 104,
Grade of Concrete	50			50.00	50	N/mm2
Grade of Steel	550			550.00	550	N/mm2
b	2000.00			2000.00	2000.00	
d	2500.00			2500.00	2500.00	
Pu	13314.14	13314.14	12977.52	12343.10	13016.54	kN
Mux	12290.86	12290.86	6649.63	8971.45	8198.42	kN-m
Muy	1846.69	1846.69	3179.87	2381.52	7537.88	kN-m
d'/D	0.030			0.030	0.030	
α	1.01	1.00	1.00	1.00	1.00	(for circular & eliptical as per
Assume Pt	**0.500**	**0.500**	**0.500**	**0.500**	**0.500**	IRC:112-2020, Cl:8.3.2, Pg no 75)
Ast Required (As pro)	25000.0	25000.0	25000.0	25000.0	25000.0	
p / fck	0.0100	0.0100	0.0100	0.0100	0.0100	
Pu/(fck*b*D)	0.053	0.053	0.052	0.049	0.052	
Mu/(fck*b*D*D)	0.035	0.035	0.035	0.035	0.035	(from Chart 47, using SP-16)
Mu/(fck*D*b*b)	0.035	0.035	0.035	0.035	0.035	(from Chart 47, using SP-16)
Mu (Longer Direction)	21875	21875.0	21875.0	21875.0	21875.0	kN-m
Mu (shorter Direction)	17500	17500.0	17500.0	17500.0	17500.0	kN-m (Resisting moment for provided steel)
Interaction ratio	$\left(\frac{M_{Edx}}{M_{Rdx}}\right)^{a} + \left(\frac{M_{Edy}}{M_{Rdy}}\right)^{a} \le 1$			(8,971.45/21,875.00) ^1.00 + (2,381.52/17,500.00) ^1.00	(8,198.42/21,875.00) ^1.00 + (7,537.88/17,500.00) ^1.00	
				0.41 + 0.14	0.37 + 0.43	
	0.66	**0.67**	**0.48**	= 0.55	= 0.80	< 1.00
	Hence O.K			**Hence O.K**	**Hence O.K**	

Total Area of steel required	25000	25000	25000	25000	25000	mm^2
Ast Provided =	Y25	-	56 Nos	Y25 - 56 Nos	Y25 - 56 Nos	
	27488.9			27488.9	27488.9	
Total Area of Steel provided	27488.94			27488.94 mm^2	27488.94 mm^2	
Provided pt	0.563			0.563	0.563	
	Hence O.K			Hence O.K	Hence O.K	

Pier is checked for Max P, Max ML and Max MT cases under normal combination

As per IRC 112-2020 Cl:16

Ast.Min =	3062.252 mm^2	$0.1N_{Ed}/f_{yd}$
Ast.Min =	10000 mm^2	0.002 Ac
Ast.Min =	12000 mm^2	0.0024 Ac
Ast.Max =	200000 mm^2	0.004Ac

Lateral ties

As per IRC:112-2020, Cl:16.2.3,

Dia of lateral tie is max of below,

i). 8 mm

ii). One quarter of max dia of longitudinal bars 8 mm

Hence provide 8 mm

Spacing of lateral tie is min of below,

i). 12 times min dia of longitudinal bars 384.00 mm

ii). The least dimension of the column 1767.77 mm

iii). 200 mm 200.00 mm

Hence provide 150

Hence provide Y - 8 @ 150 c/c

Summary

1 *Pier Size =* *(Circular Pier* 2500 mm Dia)

2 *Grade of concrete =* *M - 50*

3 *Grade of steel =* *Fe - 550*

4 *Main Longitudinal reinforcement=* **Y- 25 of 56 Nos**

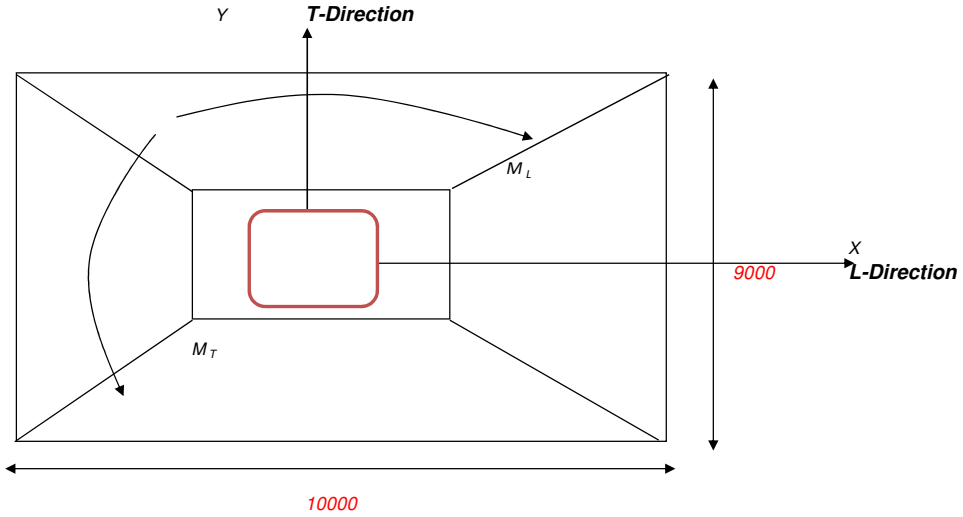
5 *Lateral Ties =* ***Y - 8 @ 150 c/c*** **above the confinement reinforcemnt.**

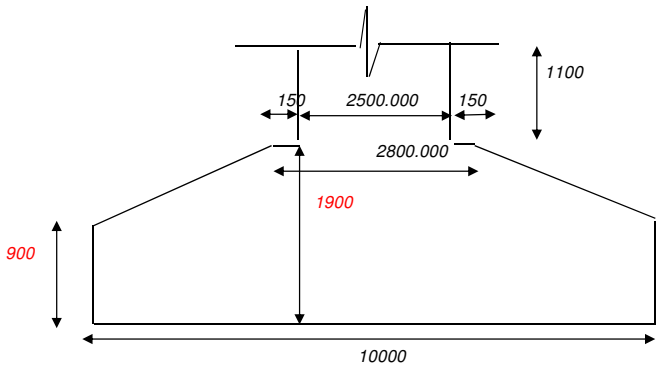
4) DESIGN OF FOUNDATION

AS PER IRC6:2017, TABLE 3.4, PAGE NO 71, THE LOAD FACTORS IS AS UNDER

Sl Nos	*Loads*	*For Footing*			*For SBC*		
		VLL is Leading & Wind is accompanying	*Wind is Leading & VLL is accompanying*	*Seismic is Leading & VLL is accompanying*	*VLL is Leading & Wind is accompanying*	*Wind is Leading & VLL is accompanying*	*Seismic is Leading & VLL is accompanying*
1)	*SW =*	***1.35***	1.35	1.35	***1.00***	1	1

2)	SIDL(W/o WC) =	**1.35**	1.35	1.35	**1.00**	1	1
3)	WC =	**1.75**	1.75	1.75	**1.00**	1	1
4)	VLL =	**1.50**	1.15	0.75	**1.00**	1	0.2
5)	BRAKING FORCE =	**1.50**	1.15	0.75	**1.00**	1	0.2
6)	WIND =	**0.90**	1.5	-	**1.00**	1	-
7)	Seismic =	-	-	1.5	-	-	1





SELF WEIGHT OF FOUNDATION:

Length of Footing (Longitudinal) =	*10000.0*	*mm*
Width of Footing (Transverse) =	*9000.0*	*mm*
Thickness of Footing =	*1900.0*	*mm*
Height of soil =	*1100.0*	*mm*
Sw of the foundation =	*3029.3*	*kN*
Rectangular portion =	*81.0*	m^3
Traphezoidal portion =H/3 ((A1+A2+Sqrt(A1xA2)) =	*40.2*	m^3
Total volume =	*121.2*	m^3
Wt of soil =		*kN*
Rectangular portion =	*270.0*	m^3
Total volume =	148.8	m^3
Wt of soil =	2976.567445	*kN*
SBC =	450.00	*kN/m2*

Load Factors as per IRC 6-2017 Table B.3

Sl Nos	Loads	VLL is Leading & Wind is accompanying	Wind is Leading & VLL is accompanying
1	SW =	1	1
2	SIDL(W/o WC) =	1	1
3	WC =	1	1
4	VLL =	1	0.75
5	BRAKING FORCE =	1	0.75
6	WIND =	0.6	1
7	Seismic =	1	-

Load Combinations

C1 to C4 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + FF)*
C5 to C8 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + FF)*
C9 to C12 = *DL+VLL ON ONE SPAN (WITH OUT IF)+(BF + SF) +WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*
C13 to C16 = *DL+VLL ON BOTH SPAN (WITH OUT IF)+(BF + SF)+WIND ON SUPER STRUCTURE +WIND ON LIVE LOAD +WIND ON PIER CAP +WIND ON PIER*
C17 = *DL+SW+WIND ON UNLOADED STURCTURE*

i) Normal and Wind Combination (Unfactored Loads)

Combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	*Remarks*
C1	15658.3	9563.4	1396.4	739.7	87.0	744.838	Normal Comb
C2	15357.6	7620.8	1845.9	597.5	87.0	603.843	Normal Comb
C5	15092.4	7945.8	1286.2	712.8	87.0	718.071	Normal Comb
C6	15519.5	6669.7	2021.4	598.1	87.0	604.359	Normal Comb
C9	15522.1	7387.9	1908.5	574.7	145.0	592.735	Wind Comb
C10	15296.5	5930.9	2245.7	468.1	145.0	490.021	Wind Comb
C13	15097.6	6167.7	1825.9	554.5	145.0	573.152	Wind Comb
C14	15417.9	5208.8	2377.3	468.5	145.0	490.394	Wind Comb
C17	15501.0	269.5	269.5	36.2	145.0	149.413	Wind Comb

ii) Seismic Combinations (Unfactored Loads)

C1 = DL+SW of pier + Secondary Force (P+ML +0.3MT) *Seismic in Longitudinal direction*
C2 to C5 = DL+0.2xVLL (with out IF) one span+0.2x(BF , FF) (P+ 0.3ML+ MT)
C6 to C9 = DL+0.2xVLL (with out IF) both span+0.2x(BF,FF) (P+ 0.3ML+ MT) } *Seismic in Transverse direction*

Seismic Forces in Longitudinal Direction

combinations	P in kN	M_L in kNm	M_T in kNm	HL	HT	H=√HL^2+HT^2	Remarks
C1	14797.43	9716.41	2459.13	691.95	437.68	818.752	Seismic
Seismic Forces in Transverse Direction							
C2	15246.38	7116.77	8084.34	609.96	691.86	922.345	Seismic
C3	14960.89	6728.24	7918.58	581.52	674.87	890.849	Seismic
C6	15252.14	6903.80	8062.29	616.33	691.86	926.572	Seismic
C7	14964.36	6730.99	7953.68	601.27	674.87	903.868	Seismic

i) Normal and Wind Combination (Unfactored Loads)

COMB	P in kN	M_L in kNm	M_T in kNm	P1	P2	P3	P4	Remarks
C1	15658.3	9563.4	1396.4	248.1	227.4	99.9	120.6	*Normal Comb*
C2	15357.6	7620.8	1845.9	235.1	207.8	106.2	133.5	*Normal Comb*
C5	15092.4	7945.8	1286.2	230.2	211.1	105.2	124.2	*Normal Comb*
C6	15519.5	6669.7	2021.4	231.9	201.9	113.0	142.9	*Normal Comb*
C9	15522.1	7387.9	1908.5	235.9	207.6	109.1	137.4	*Wind Comb*
C10	15296.5	5930.9	2245.7	226.1	192.9	113.8	147.1	*Wind Comb*
C13	15097.6	6167.7	1825.9	222.4	195.3	113.1	140.2	*Wind Comb*
C14	15417.9	5208.8	2377.3	223.6	188.4	119.0	154.2	*Wind Comb*
C17	15501.0	269.5	269.5	176.0	172.0	168.4	172.4	*Wind Comb*
		For working Combination (Max)		261.07	244.31	154.22	167.19	
		For Working Combination (Min)		170.31	156.40	99.88	120.57	
		For Wind Combination (Max)		295.03	295.03	168.44	172.43	
		For Wind Combination (Min)		176.03	154.33	100.65	100.65	

ii) Seismic Combinations (Unfactored Loads)

COMB	P in kN	ML in kNm	MT in kNm	P1	P2	P3	P4
C1	14797.4	9716.4	2459.1	247.4	211.0	81.4	117.9
C2	15246.4	7116.8	8084.3	276.7	157.0	62.1	181.8
C3	14960.9	6728.2	7918.6	269.7	152.4	62.7	180.0
C6	15252.1	6903.8	8062.3	275.2	155.8	63.7	183.2
C7	14964.4	6731.0	7953.7	270.1	152.2	62.5	180.3

For Seismic Combination (MAX)	276.73	210.98	126.06	238.55
For Seismic Combination (MIN)	235.85	123.36	62.08	117.86

iii) Normal and Wind Combination (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	P1	P2	P3	P4	Remarks
C1	21422.05	14345.15	2094.56	349.2	318.1	126.9	157.9	*Normal Comb*
C2	20970.98	11431.14	2768.85	329.7	288.7	136.3	177.3	*Normal Comb*
C5	20573.10	11918.67	1929.25	322.34	293.76	134.84	163.42	*Normal Comb*
C6	21213.76	10004.58	3032.06	324.9	279.9	146.6	191.5	*Normal Comb*
C9	21245.11	10810.61	2874.24	329.42	286.84	142.70	185.28	*Wind Comb*
C10	20899.29	8810.28	3391.19	316.1	265.8	148.4	198.6	*Wind Comb*
C13	20594.26	9454.75	2747.50	312.21	271.50	145.44	186.15	*Wind Comb*
C14	21085.43	7987.28	3592.99	314.1	260.9	154.4	207.6	*Wind Comb*
C17	19983.22	808.63	404.32	230.4	224.4	213.6	219.6	*Wind Comb*
			Max	349.172	318.142	213.650	235.535	
			Min	230.422	208.551	126.873	157.904	

iv) Seismic Combinations (Factored Loads)

COMB	P in kN	ML in kNm	MT in kNm	P1	P2	P3	P4
C1	20237.22	14574.62	4102.02	352.4	291.6	97.3	158.1
C2	21027.07	10675.16	12126.50	394.6	215.0	72.6	252.3
C3	20602.27	10092.36	11877.87	384.2	208.2	73.6	249.6
C6	21088.25	10352.93	12093.44	392.91	213.75	75.71	254.88
C7	20641.25	10092.99	11930.52	385.0	208.3	73.7	250.4
			Max	394.628	291.637	119.104	287.834
			Min	333.391	164.661	72.640	158.079

Design of Footing

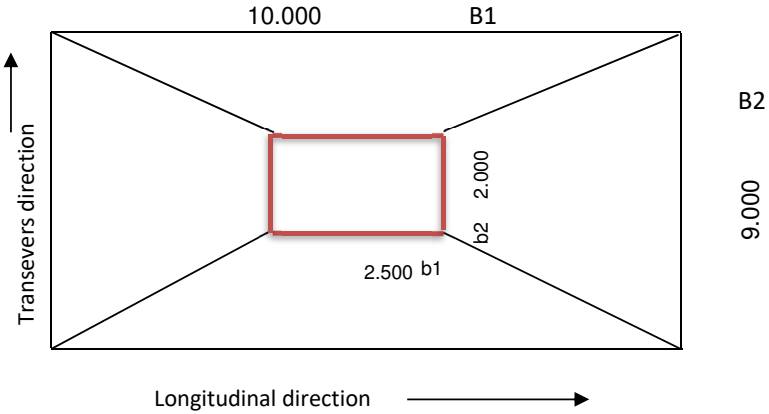
Footing Design is carried out for the Critical combination adopting Limit State Load factors and Partial safety factors for Material, as per IRC:6-2017/IRC:112-2020

Load Combination =

Pu=	21422.048 KNm	This load is the combination of	Normal Comb	for C1
ML=	14345.152 KNm	Longitudinal Design		
MT=	2094.562 KNm			

Pu=	21088.251 KNm	This load is the combination of	Seismic	for C6
ML=	10352.926 KNm	Transverse Design		
MT=	12093.441 KNm			

Footing width in span direction (longitudinal)	(B1)=	10.000 m
Footing width in road way direction (Transverse)	(B2)=	9.000 m
Depth of footing (under column)	(D) =	1.900 m
Depth of footing (at edges)	(D1) =	0.900 m
Dimension of column in span direction	(b1)=	2.500 m
Dimension of column in road way direction	(b2)=	2.000 m
Depth of soil fill at the face of column	=	1.100 m
Depth of soil fill at edge	=	2.100 m



Dia of bars in the span direction	(ds)=	25 mm		
No. of bars	(ns)=	70 No.	in	9.0 m
spacing of the rods	(ss)=	100.000 mm		length
Dia of bars in the road way direction	(dr)=	25 mm		
No. of bars	(nr)=	70 No.	in	10.0 m
spacing of the rods	(sr)=	100.000 mm		length
Edge thickness of footing	(D1)=	0.900 m		
Clear cover to main bars	(d')=	75 mm		
Grade of concrete	(GC)=	M 35		
Grade of steel	(GS)=	550		
Offset of footing top (min 150 mm)	(off)=	0.150 m		

Top dimension of footing (span direction) (B1') = b1+2* offset

= 2.800 m

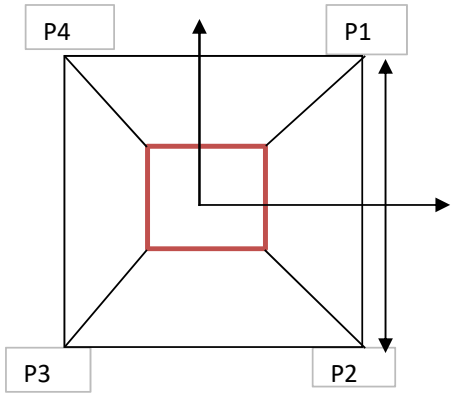
Top dimension of footing (Road way direction) (B2') = b2+2* offset + 2.000 m x 2

= 2.300 m

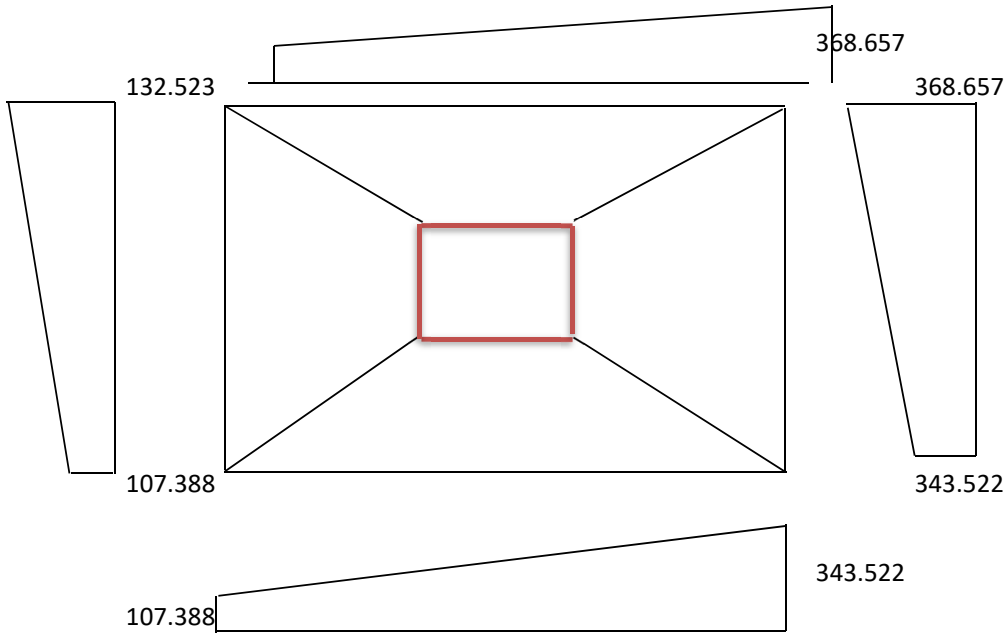
Area of base of footing (A1) = 90 sq.m

Area of top of footing (A2) = 6.44 sq.m

PRESSURES UNDER FOOTING AT ALL CORNERS :



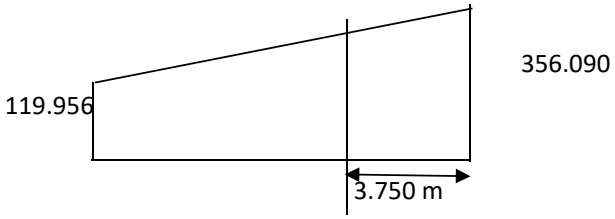
Pmax	(P1) = 368.657	KN/sqm
Pmin	(P3) = 107.388	KN/sqm
	(P2) = 343.522	KN/sqm
	(P4) = 132.523	KN/sqm



Pmax	=	368.657	KN/sqm
Pmin	=	107.388	KN/sqm

A) LONGITUDINAL BENDING MOMENTS :

As per cl.307.2.1 of IRC : 21-2000, the critical section for bending in bases shall be taken at the face of the column



long side (b1)= 2.500 m

distance of critical section from one edge (X) = (B1-b1)/2

= 3.750 m

Pressure at the centre of one edge (P1,2) = (P1 + P2)/2

= 356.090 KN/sqm

Pressure at the centre of other edge (P3,4) = (P3 + P4)/2

= 119.956 KN/sqm

Pressure at critical section (Pc) = P12-((P12-P34)/B1)*X

= 267.540 KN/sqm

Hence Bending moment (BM1) = $Pc*X^2/2 + ((P12-Pc)/2)*X*2/3*X$

= 2296.217 KN/sqm

Hence total Bending moment (BM) = BM1 *B2

= 20665.952 KNm/m

Bending moment due to self weight = 1972.856 KNm/m

Bending moment due to overburden soil weight = 2253.015 KNm/m

Net Bm = 16440.081 KNm/m

Calculation of Reinforcement

Effective width resisting this BM (Ew) = = 3.138 m B2' +(B2- B2')/8

Mu / Ew*d*d = 0.133 * fck 4.66 = Q

dreq = Sqrt (Mu / Q*Ew) limiting depth

= 1060.963075 mm 2.183

dpro = D-d'-0.5d_s 2095.83

= 1812.500 mm

limiting effective depth = 2095.833 mm

min effective depth = 1812.500 mm **Hence safe**

Area of steel required (Ast) = (50*fck/0.87fy)*(1-sqrt(1-(4.5*Mu/(fck*Ew*d2))))

= 23079.88165 mm^2

a) As per IRC:112-2020, Cl:16.5.1.1,

As.min = 0.26*(fctm/fyk)*bt*d not less than 0.0013*bt*d

fctm= 2.8 Mpa from irc:112-2020, table 6.5,

bt= 9000 mm

fyk= Fe - 550 N/mm2

d= 1813 mm

As.min= 21592 mm2

Area of steel required (Ast) = **23080** mm^2

Ast req (Ast) /m run = (23,079.88 / 9)

= 2307.988165 mm^2

no of bars required = **47.02** Nos.

Required Spacing of bars = 212.7 mm

Hence provide = **25** mm Dia **70** Nos

Ast prov = **34361.17** mm^2

Spacing of bars provided = say **100 mm**

Hence provide **25** **100** **c/c**

Hence safe

CHECK FOR SHEAR (LONGITUDINAL DIRECTION) :

As per IRC the critical section for one way shear is considered at a distance equivalent to the eff. depth from the face of the column

Hence the distance of the critical section from the edge (X) = $(B1-b1)/2-d_{prov}$

= 1.938 m

Pressure at the critical section (P_c) = P12-(P12-P34)/B1*X

= 310.339 KN/sqm

Pressure force at the critical section (SF1) = Pc*X + ((P12-Pc)/2)*X

= 645.603 KN

Total pressure force (SF) = SF1 * B2

5810.425229 kN

shear force due to self weight = 516.2295 kN

shear force due to overburden soil weight = 646.7664 kN

Net shear force (V) = 4647.429 KN

Bending moment at the critical section (BM1) = $Pc*X^2/2 + ((P12-Pc)/2)*X*2/3*X$

= 639.740 KN/sqm

Total Bending moment (BM) = BM1 *B2

5757.658163 KNm/m

Net Bending moment (BM) = 5633.327 KNm/m

Depth at critical section for shear (D_c) = D1 + 2(D-D1)/(B1-B')*X

= 1.438 m

Hence Eff depth (d_c) = D_c - d'-0.5d_s = 1350.694444 mm

limiting effective depth = 1458.333333 mm

min effective depth = 1350.694 mm

Net shear force (V) = SF - BM/(d_{prov})*tan β

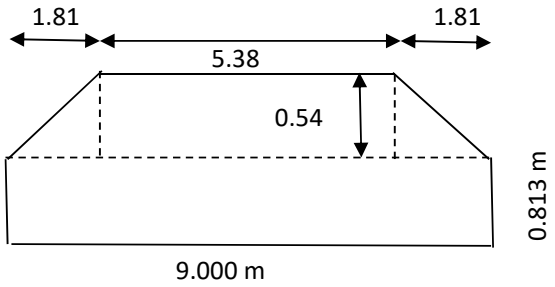
tan β = 2 * (D - D1)/(B1 - B1')

= 0.277778

= 3488.904 KN

Ultimate shear force (Vu) = = 3488.90 kN

= 3488.90 kN



Cross section at critical distance

Width available at critical section (Wc) = B1' + (B1-B1')/(D- D1)*(D-D_C)

= 6.125 m

Effective depth at edge (d_e) = D1 - d' -0.5*d_s

= 812.500 mm

Hence eff. Area resisting shear (A_{eff}) = 9.00 x 0.81 + 0.54 x (1.81+5.38)

= 11180772.569 mm^2

Hence shear stress induced τ_v = Vu / A_{eff}

= 0.312045024 N/mm^2

100 A_s / bd = 0.307

For this value of 100 A_s / bd

Permissible shear stress = 0.400 N/mm^2

Hence safe

Check For Shear as per cl. 10.3.2, IRC:112-2020

V_{Rdc} = $(0.12K(80\rho 1 f_{ck})^{0.33}+0.15\sigma cp)bw.d$

Where,

K= $1+\sqrt{200/d}$

A. Longitudinal Direction

d= 1458.333 mm

K= 1.370

ϑ1 0.0031

bwXd= Effective Area= 11180772.569 mm^2

Neglecting Axial Force, σcp =0

V_{Rdc} = 3740.64 KN

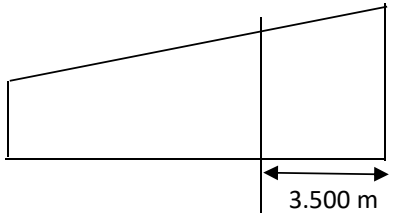
> 3488.90 KN **ok**

Shear Reinforcement Not Reqd

B) TRANSVERSE BENDING MOMENT :

Pmax	(P1) = 392.084		KN/sqm
Pmin	(P3) = 76.544		KN/sqm
	(P2) = 246.963		KN/sqm
	(P4) = 221.665		KN/sqm

As per cl.307.2.1 of IRC : 21-2000, the critical section for bending in bases shall be taken at the face of the column



distance of critical section from one edge (X) = (B2-b3)/2

= 3.500 m

Depth at critical section = 1.945 m

Pressure at the centre of one edge (P41) = (P1 + P4)/2

= 306.875 KN/sqm

Pressure at the centre of other edge (P23) = (P2 + P3)/2

= 161.753 KN/sqm

Pressure at critical section (Pc) = P41-((P41-P23)/B2)*X

= 250.438 KN/sqm

Hence Bending moment (BM1) = $Pc*X^2/2 + ((P12-Pc)/2)*X*2/3*X$

= 1764.383 KN/sqm

Hence total Bending moment (BM) = BM1 *B1

= 17643.830 KNm/m

Bending moment due to self weight = 1911.072917 KNm/m

Bending moment due to overburden soil weight = 2181.891667 KNm/m

Net Bm = 13550.866 KNm/m

Calculation of Reinforcement

Effective width resisting this BM (Ew) = b1' +(B1- b1')/8

= 3.438 m

Mu / Ew*d*d = 0.133 * fck

= 4.655 = Q

dreq = Sqrt (Mu / Q*Ew)

= 920.24 mm

Effective depth provided (d_{prov}) = D-d'-1.5d/2

= 1787.500 mm

limiting effective depth = 1954.166667

min effective depth = 1787.500 mm **Hence safe**

Area of steel required (Ast) = (50*fck/0.87fy)*(1-sqrt(1-(4.5*Mu/(fck*Ew*d2))))

= 18592.57984 mm^2

a) As per IRC:112-2020, Cl:16.5.1.1,

As.min = 0.26*(fctm/fyk)*bt*d not less taha 0.0013*bt*d

fctm= 2.8 Mpa from irc:112-2020, table 6.5,

bt= 10000.000 m mm

fyk= 550 N/mm2

d= 1788 mm

As.min= 23660 mm2

Area of steel required (Ast) = **23660** mm^2

Area of steel required (Ast) /m run = 2628.888889 mm^2

no of bars required **48.20** Nos.

Spacing of bars Required = 186.7229 mm

25 mm Dia **70** Nos

Area of steel provided (Ast prov) = **34361** mm^2

Spacing of bars provided = **143.00** say 100

Area of steel provided (Ast prov) = 34361.17 mm^2

Hence Provide **25** **100** **c/c**

Hence safe

CHECK FOR SHEAR (TRANSVERSE DIRECTION) :

As per IRC the critical section for one way shear is considered at a distance equivalent to the eff. depth from thr face of the column

Hence the distance of the critical section from the edge (X) = $(B2-b3)/2-d_{prov}$

= 1.713 m

Pressure at the critical section (P_c) = P41-(P41-P23)/B2*X

= 279.261 KN/sqm

Pressure force at the critical section (SF1) = Pc*X + ((P41-Pc)/2)*X

= 501.879 KN

Total pressure force (SF) = SF1 * B1

5018.787331 kN

shear force due to self weight = 559.7423 kN

shear force due to overburden soil weight = 631.708 kN

= 3827.337 KN

Bending moment at the critical section (BM1) = $Pc*X^2/2$ + ((P41-Pc)/2)*X*2/3*X

= 436.482 kNm

Total Bending moment (BM) = BM1 *B1

4364.820389 KNm/m

bending moment due to self weight 44.39434 kNm

= 4263.837 KNm/m

Depth at critical section for shear (D_c) = D1 + 2(D-D1)/(B2-B')*X

= 1.411 m

Hence Eff depth (d_c) = D_c - d'-d_r/2

= 1298.69403 mm

Limiting effective depth = 1358.333333 mm

Min effective depth= 1298.694 mm

Net shear force (V) = SF - BM/(d_{prov})*tan β

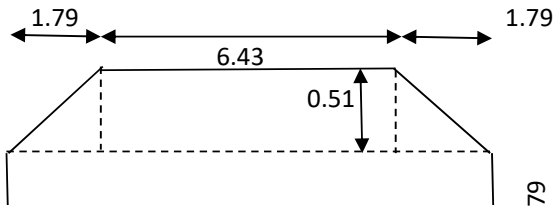
tan β = 2 * (D - D1)/(B2 - B2')

= 0.298507

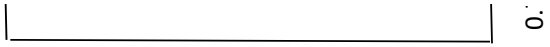
= 2847.285 KN

Width available at critical section (Wc) = B1' + (B1-B1')/(D- D1)*(D-D_C)

= 6.319 m



Effective depth at edge (d_e) = D1 - d' -d_r/2



= 787.500 mm

Hence eff. Area resisting shear (A_{eff}) = 10.00 x 0.79 + 0.51 x (1.79+6.43)

= 12073180.970 mm^2

Hence shear stress induced τ = Vu / A_{eff}

= 0.236 N/mm^2

100 A_s / bd = 0.285

For this value of 100 A_s / bd and M35 grade concrete,

Permissible shear stress = 0.388 N/mm^2

Hence safe

Check For Shear as per cl. 10.3.2, IRC:112-2020

V_{Rdc} = $(0.12K(80\rho 1 f_{ck})^{0.33}+0.15\sigma cp)bw.d$

Where, K= $1+\sqrt{200/d}$

A. Longitudinal Direction

d= 1298.694 mm

K= 1.392

ρ1 0.0028

bwXd= Effective Area= 12073180.970 mm^2

Neglecting Axial Force, σcp =0

V_{Rdc} = 4001.65 KN

> 2847.29 KN **ok**

Shear Reinforcement Not Reqd

C) PUNCHING SHEAR :

Critical section for punching shear is assumed at distance equal to half the depth from the face of the column

Perimeter = 12100.000 mm

Distance of minimum depth section from one edge (X) = (B2 - b3 - d prov)/2

= 2606.250 mm

Minimum depth available (D_c) = D1 +2(D-D1)/(B1-B')*X
= 1.624 m
Hence minimum eff. Depth available (dc) = D_c - d' -dr/2
= 1511.458 mm
Punching shear stress induced (σ) = P/ (C*dc)
= 0.872 N/mm^2

Allowable punching shear as per IRC:112-2020, Cl:10.4.5, Pg no 104,

v_{min} = 0.30
K = 1.38
ρ_l = 0.02
a = 689.26 mm
v_{Rd} = 2.50 > 1.19 = (v_{min}*2d/a)
= 2.497
= 2.497 N/mm^2 **Hence safe**

$$v_{Rd} = 0.12K(80\rho_l f_{ck})^{1/3}\frac{2d}{a} \geq v_{min}\frac{2d}{a}$$

$K = 1+\sqrt{\frac{200}{d}} \leq 2.0$ where d is depth in millimeters.

$\rho_l = \sqrt{\rho_{ly}\cdot\rho_{lz}} \leq 0.02$

$\rho_{ly}\cdot\rho_{lz}$ relate to the bonded tension steel in y - and z - directions respectively.

$$v_{min} = 0.031K^{3/2}f_{ck}^{1/2}$$

Check For Punching Shear,as per cl. 10.4.3, IRC:112-2020

v_{Ed} = $\beta V_{Ed}/u_i d$

$$\beta = 1+1.8\sqrt{\left(\frac{e_y}{b_z}\right)^2+\left(\frac{e_z}{b_y}\right)^2}$$

V_{Ed}= 21422.05
ML = 14345.15
MT = 2094.56
eL = ML/V_{Ed}
eL = 0.67
bL = 5.80
eT = MT/V_{Ed}
eT = 0.10

bT = 6.30

β = 1.2

d = 1800.0

a) At D/2 from the face of the column

Perimeter (ui) = 12100.00 mm

$v_{Ed=}$ 1.19 N/mm^2

< Rs. 2.50 **OK**

b) At face of the column

Perimeter (ui) = 9000.00

v_{Ed} = $\beta V_{Ed}/u_i d$

1.60 N/mm^2

$$\nu = 0.6\left[1 - \frac{f_{ck}}{310}\right] \quad f_{ck} \text{ in MPa}$$

v= 0.53

fcd = 0.67*fck/1.5

= 15.63

$$v_{Rd.max} = \frac{1}{2}.\nu.fcd \qquad \textbf{Eq.10.43}$$

$V_{Rd.max}$ = 4.16

> v_{Ed}

> 1.60 **OK**

Stress Check for Provided Steel (Rare Combination)

		Longitudinal Direction	Transverse Direction
Width of Footing (mm) =	b=	9000	10000
Thickness of Footing (mm)	h =	1900	1900

$Ec,eff = Ecm / (1+ \phi)$

Dia of main Bar (mm)	25	25
Effective Depth (deff) mm	1813	1788
Ast pro (mm2)	49087	44179
Max Moment (kN-m)	14745	12350
Es (N/mm^2)	200000	200000
Ecm (N/mm^2)	14101	14101
m = α = Es/Ecm	14.18	14.18
X_U (mm) =	457.8	415
L.A (mm) =	1620.2	1613
Stress in Steel (N/mm2)	185.4	173
Permissible stress in steel	440.0	440
Check for stree in steel	Hence OK	Hence OK
Stress in Concrete (N/mm2)	4.42	3.69
Permissible stress in concrete	17	17
Check for stree in concrete	Hence OK	Hence OK

Ecm = 32000 MPa (as per IRC-112, table-6.5)

As per IRC:112-2020, table-6.9, for RH-80%, & 28 days age loadi

ø 1= 1.9 for 150

ø 2= 1.7 for 600

ø = **1.27** for 1569 2Ac/u = 1568.81

Ec,eff = 14100.53

Crack Width Calculation As per IRC 112-2020

	Longitudinal Direction	Transverse Direction
Dia of main Bar (mm)	25	25
Spacing of Bars (mm)	100	100
Max Moment (kN-m)	16107.11	12117.577
Ast pro As (mm^2)	49087.39	44179
C_{min} (mm)	75	75
a_{cr} (mm)	88.28	88.28
h (mm)	1900.00	1900.00
d (mm)	1812.50	1787.50
Es (N/mm^2)	200000	200000
Ecm (N/mm^2)	14101	14101
m = α = Es/Ecm	14.18	14.18
Xu (mm)	457.82	414.77

σ_{sc} (N/mm^2)	202.52	170.02
k_t =	0.5	0.5

$f_{ct,eff}$ (N/mm^2)		2.8	2.8
$A_{c,eff} = b*h_{c,eff}$ (mm^2)		1968750.00	2812500.00
$h_{c,eff}$ least of	*2.5 (h - d)*	218.8	281.3
	(h - Xu/3)	480.7	495.1
	h / 2	950.0	950.0
$\rho_{P,eff}$ =		0.0249	0.0157
$\varepsilon_{sm} - \varepsilon_{cm}$ =		0.0006	0.0003
		≥ 0.0006	≥ 0.0005
$\varepsilon_{sm} - \varepsilon_{cm}$ =		0.0006	0.0005
IRC 112-2020	k1 =	0.8	0.8
	k2 =	0.5	0.5
Spacing	5(c + F/2) =	312.50	312.50
Case(i)	$S_{r.max}$ $(mm)_=$	425.45	525.56
Case(ii)	$S_{r.max}$ (mm) =	1874.83	1930.79
$S_{r.max}$ (mm) =		425.45	525.56
W_k (mm) =		0.269	0.268
Check for Crack Width		***Hence OK***	***Hence OK***